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DESIGN, ANALYSIS AND OPTIMIZATION OF AN ORANGE PEEL GRAPPLE

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DATE AND SIGNATURE

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<u>THESIS DEVELOPER'S SIGNATURE</u>:

JUAN GABRIEL GLARÍA ABRIL

ACKNOWLEDGES

With the present project I finish my Industrial Engineering studies. It has been a long path of seven years that I couldn't have done without all the people that helped me directly or supporting me. All these people deserve being mentioned on this project. And my apologies if I forget somebody, but they have to know that these acknowledges are dedicated to those who have participated by helping me.

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1. INTRODUCTION AND GOALS

1.1 INTRODUCTION

An Orange Peel Grapple is a tool used by cranes or other machines in to pick up, translate and deposit some materials.

In the market we can find a lot of different kinds of grapples for cranes, but Orange Peel Grapples are specialized in taking materials like metal scrap, debris and others similar to them.

It usually has three important parts: the main body, the peels and the cylinders that connect the main body with the peels. Of course, in order to make these connections, we need secondary elements like pins, washers or nuts.

The hydraulic circuit is located most of the times inside the main body from where they reach the cylinders. This hydraulic system is governed by the operator inside the vehicle.

Grapples are connected with the vehicle that is carrying them with articulated and hydraulic arms.

1.2 GOALS

The present project has three main goals: one of design, other of analysis and other of optimization of the model.

We will start creating the design of the model taking some references from some companies specialized in orange peel grapples considering minimum and maximum opening angles, weights, etc.

Once we have the design already, we can measure the fixed distances and angles we need to do the necessary calculation.

We will theoretically analyze the model and later we will analyze it with the help of a CAD program.

With the analysis, we will be able to check if our model can withstand the weights and forces on the most critical parts.

In the end, we will propose some optimization options to improve the model.

2. GRAPPLES

2.1 CONCEPTS ABOUT GRAPPLES

A grapple or grab is a mechanical device with two or more jaws, used to pick objects up or to capture objects.

A grapple can be mounted on a tractor or on an excavator with a movable arm that may lift, extend, retract and move side-to-side (pivot or rotate). Some machines also have a separate control for rotating the grapple.

There are three different ways to open/close the grab:

- Electro – hydraulic

Figure 1: Electro-hydraulic grapple

The clamshells of electro-hydraulic grabs are opened and closed with hydraulic cylinders. The drive-unit for this is an electro-motor with a hydraulic pump. The drive-unit of the grab needs an electrical power-supply from the crane over a cable. Through this cable, the grab also receives its commands.

- Diesel – hydraulic (similar to electro – hydraulic)

Figure 2: Diesel-hydraulic grapple

The clamshells of radio controlled diesel-hydraulic grabs are opened and closed with hydraulic cylinders. The drive-unit for this is a diesel-motor with hydraulic pump. The commands are given by the crane driver over a radio control to the grab. The crane does not need any additional equipment to operate these grabs. The grabs can be operated on every kind of crane. The effectiveness is like electro-hydraulic grabs, in special cases even better.

- Mechanical by ropes

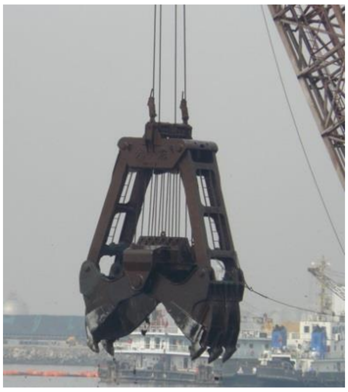


Figure 3: Mechanical rope grapple

Mechanical rope grabs are opened and closed by means of ropes directly from the crane. The system is like block and tackle. According to the crane type, there are different types of mechanical rope grabs:
Single rope grabs, 2-rope grabs (1 holding rope, 1 closing rope), 3-rope grabs and 4-rope grabs (2 holding ropes, 2 closing ropes).

Grabs can be used by:

- <u>Mobile cranes</u>

Figure 4: Mobile crane

- <u>Fixed cranes</u>

Figure 5: Fixed crane

2.2 TYPES OF HYDRAULIC GRAPPLES

Figure 6: Several types of hydraulic grapples

The following are some of the most important types of grapples that can be found in factories, shown with a brief description.

Contractors' Grapples

Contractors' Grapples handle irregularly shaped loads and loose materials. They are an essential tool for demolition, sorting, and reprocessing work.

Figure 7: Contractors' grapple

Demolition and Sorting Grapples

Demolition and Sorting Grapples are heavy-duty units designed for applications involving demolition of non-concrete structures, material handling/sorting at recycling and waste transfer facilities, site cleanup and loading/sorting construction or demolition debris. They have an impressive force and precision and they can handle bulky loads.

Figure 8: Demolition and sorting grapple

Log grapples

Log grapples are all of the modern bypass design, allowing wide opening widths and capacity but still allowing very tight closing for secure gripping of uneven loads. They are used in general forestry applications.

Figure 9: Log grapples

Orange peel grapples

Orange peel grapple is explained in point 2.2.1.

Solid Waste Grapples

Solid Waste Grapples are specifically designed for roadside pick-up of trash, brush, white goods, animal carcasses, etc. and for handling light, loose scrap metals, scrap bales, etc.

Figure 10: Solid waste grapple

Clamshell buckets

Clamshell buckets are suitable for digging and loading soil, sand and similar materials.

Figure 11: Clamshell buckets

2.2.1 ORANGE PEEL GRAPPLES

Figure 12: Orange peel grapple

Orange peel grapples are used to handle recycling material and metal scrap piles. Cylinders work together creating the clamping force required to penetrate deeply into these scrap piles and grab tight to move the maximum possible amount of material in every pass. This type of grapple provides superior productivity and efficiency for material handling operations. Cylinders are usually protected from the possible external threats or impacts.

Some orange peel grapples have an engine to rotate the grapple and may also include an electromagnet to facilitate the collection of metallic materials.

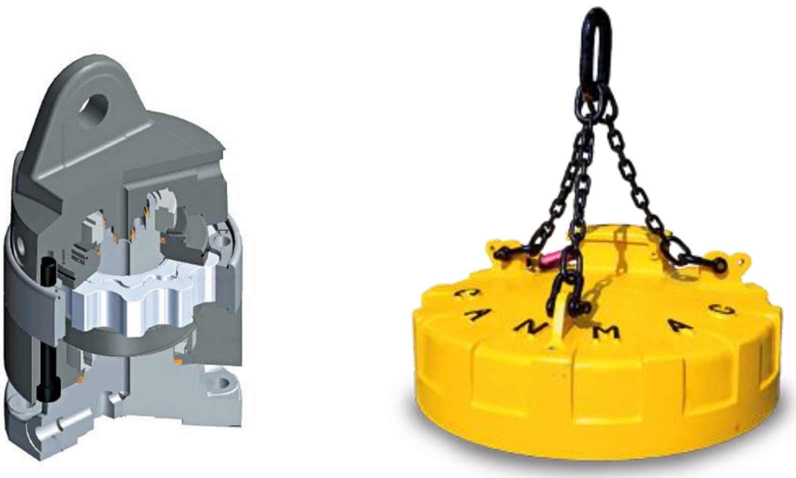


Figure 13: Left: rotating engine; Right: electromagnet

Depending on the amount of material that the user needs to lift, it is possible to find orange peel grapples with 4, 5 or 6 peels.

Figure 14: Left: 4 peel grapple; Center: 5 peel grapple; Right: 6 peel grapple

They are widely used in ports, shipping, mine, metallurgy, architecture, waste treatment plan, etc.

3. FEATURES OF THE ORANGE PEEL GRAPPLE

In order to submit this model to forces and other physical interactions, it is necessary to define the material from which we are going to build each element.

We are going to consider that all the elements are built with the same material. This won't suppose a big difference from a real model, because the only elements that have a different behavior would be the washers.

But in this project we haven't got longitudinal forces in the pins, so the washers won't have to withstand any force.

3.1 MATERIAL

So, according to the solicitations that the orange peel grapple is going to receive and checking some orange peel grapples from some companies, we have concluded that we will use a S620Q steel (number 1.8914). S620Q is a high strength weldable steel used in structural, pressure vessel and engineering applications.

3.2 PHYSICAL PROPERTIES

The physical properties of the chosen steel are as follows:

- Yield limit = 620e+6 $\mathrm{N/m^2}$

- Tensile strength = 724e+8 $\mathrm{N/m^2}$

- Modulus of elasticity= 210e+9 $\mathrm{N/m^2}$

- Density = 7800 $\mathrm{kg/m^3}$

The grapple characteristics we choose, taking notice of the grapples provided by different companies are:

- Optimum Operating pressure of the cylinder =400 bar.

- Weight that it can lift = 780 kg.

3.2.1 RANGE OF MOVEMENT

We have to define the position of the tongs when they are fully open and fully closed.

In point 5.2, these positions are described in relation to an angle that we will also later explain.

These are the important lengths when the grapple is fully open and fully closed:

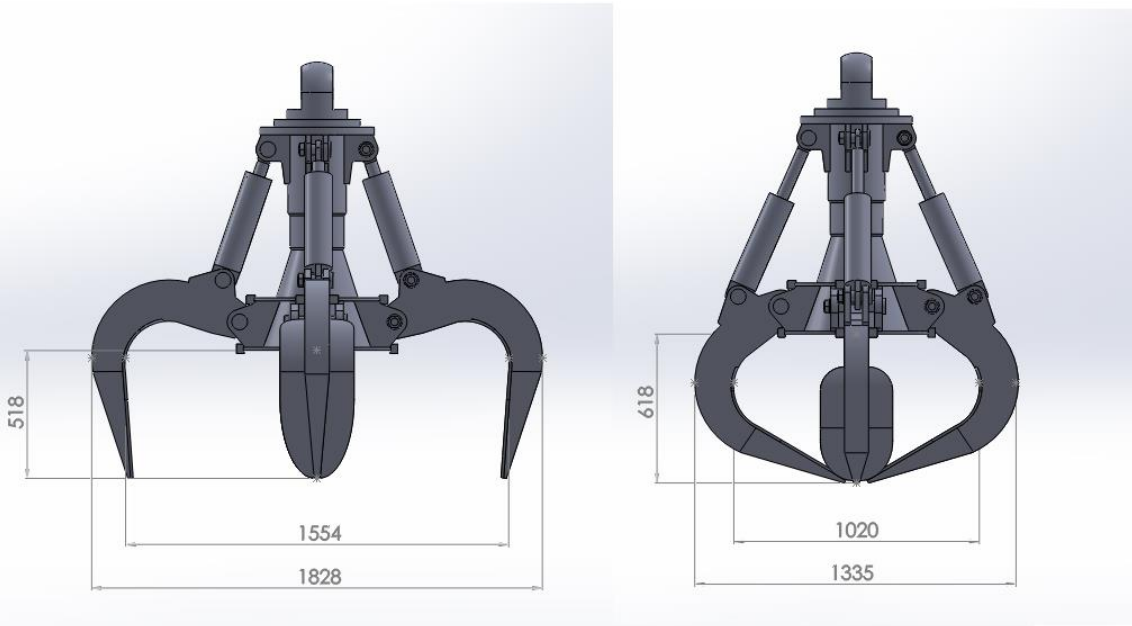


Figure 15: lengths (open and closed)

4. BUILDING THE MODEL

For this model, we have taken some drawings of commercial products as reference, but finally, we have built our own model taking into account the features we needed.

In our model, we haven't added rotating engine neither electromagnet.

4.1 PRESENTATION OF THE MODEL

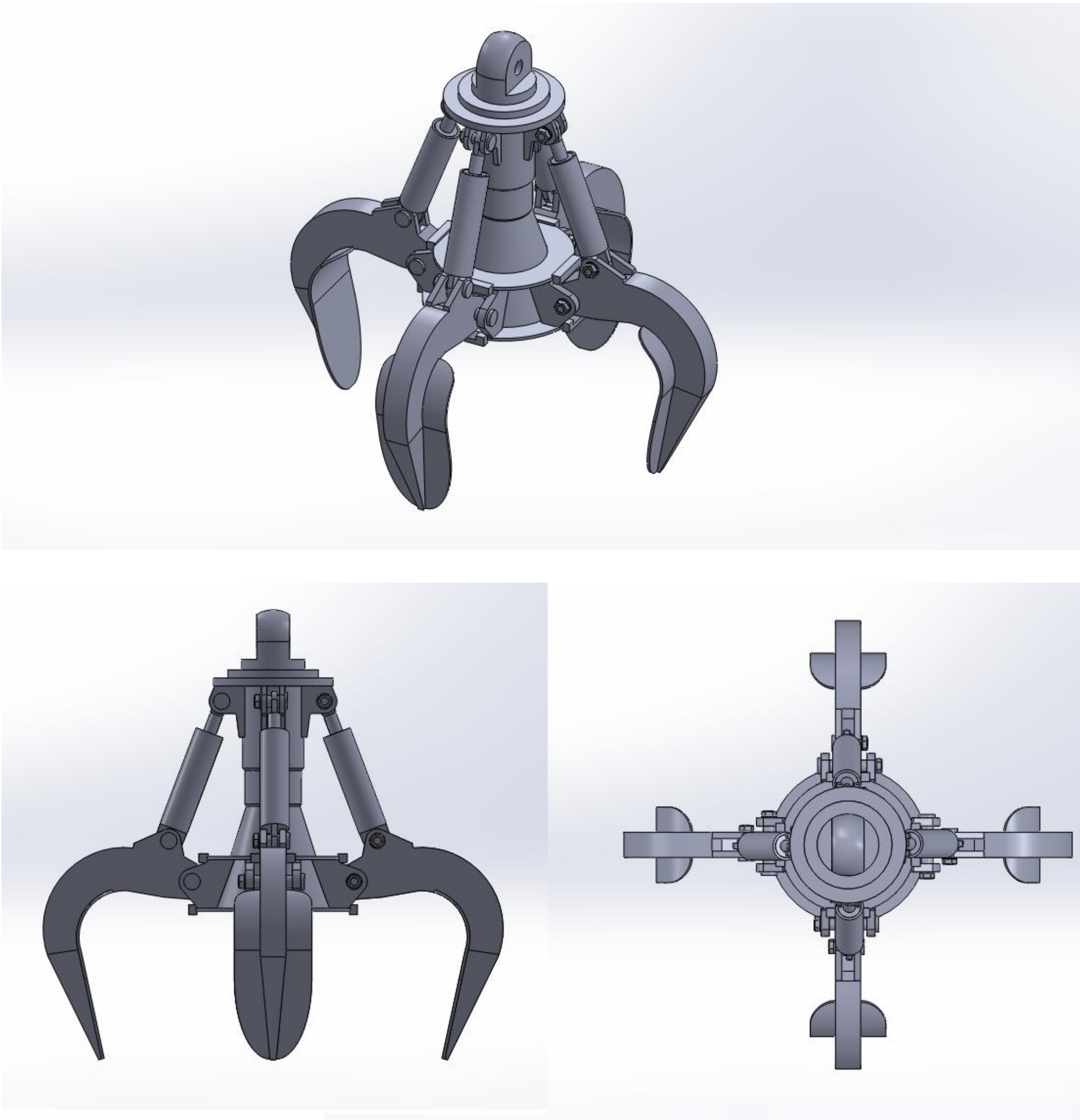


Figure 16: Views of the entire model

4.1.1 EXPLODED MODEL

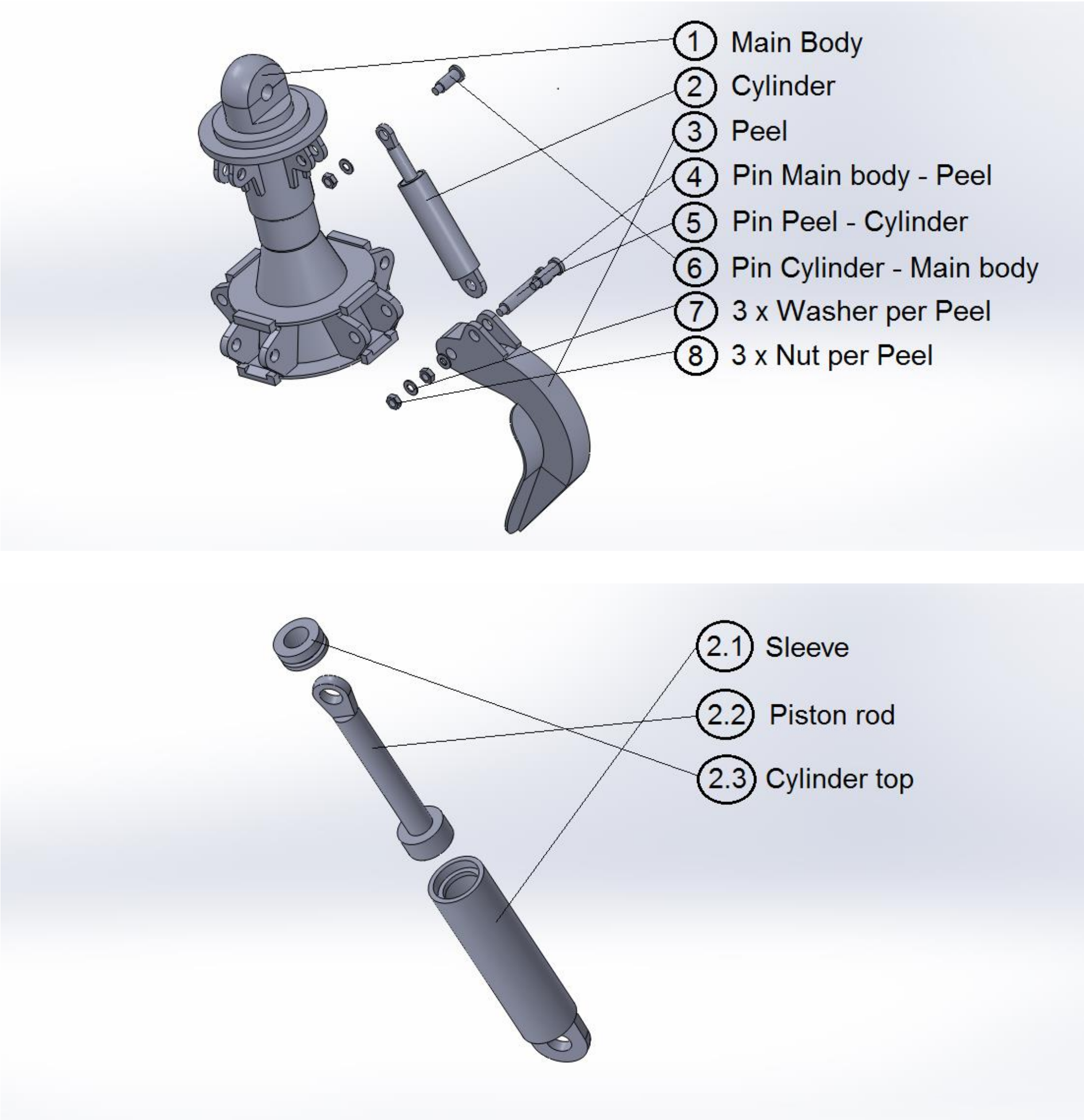


Figure 17: Exploded model

4.2 DESCRIPTION OF PARTS

Based on the exploded model, we are going to introduce each part separately:

1- Main body: The element that sustains the rest of the elements. It supports all the loads and weights of the grapple.

2- Cylinder: It has the mission of moving the peels with a hydraulic system.
   - 2.1- Sleeve: The outside of the cylinder that contains the fluid.
   - 2.2- Piston rod: Element that with the sleeve, perform the movement of the cylinder
   - 2.3- Cylinder top: This piece is necessary to keep the sealing.

3- Tong, Peel or Orange peel: Important part of the model that directly receives the weight of the load and doesn't let it fall down.

4- Pin Main body – Peel: Joint between these two elements

5- Pin Peel – Cylinder: Joint between these two elements

6- Pin Cylinder – Main body: Joint between these two elements.

7- Washers: They endure the tightening force.

8- Nuts: They don't let the pins and other parts move in the longitudinal direction.

Figure 18: From top to down and from left to right: 1- Main body; 2- Cylinder; 3- Peel; 4- Pin; 5- Washer; 6- Nut

5. THEORETICAL ANALYSIS

5.1 OPERATION PROCESS

Para obtener las fuerzas y las reacciones del modelo, vamos a establecer algunos puntos necesarios para resolver las ecuaciones. Empezaremos con las pinzas porque recibirán directamente el peso de la carga. Con este peso, calcularemos la fuerza que el cilindro tiene que realizar cuando las pinzas están abiertas un determinado ángulo.

Sabiendo la fuerza del cilindro, es posible calcular las reacciones en las pinzas, cilindros y en el cuerpo principal.

Vamos a construir las ecuaciones genéricas para poder usarlas en otros cálculos, como en la optimización.

Finalmente, analizaremos los puntos críticos para la máxima fuerza a la que estarán sometidos.

5.1.1 POINTS, FORCES, ANGLES ANDS DISTANCES.

POINTS:

Now we are going to show the points where we have calculated the forces and reactions.

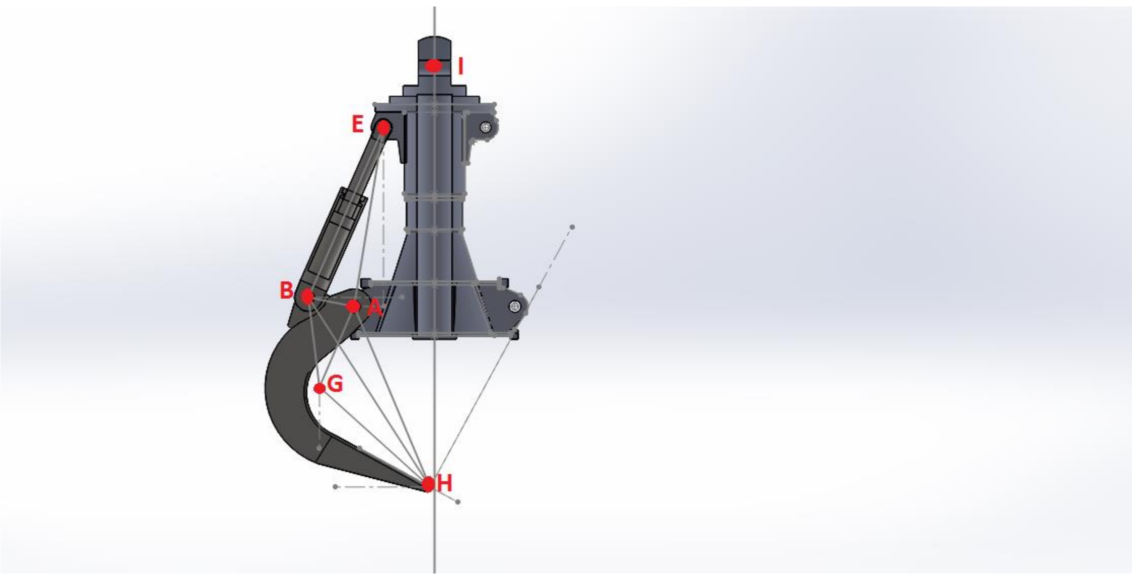


Figure 19: Calculation points

Points A, E and I are fixed in the space, while points B, G and H will rotate around point A.

FORCES:

And the main forces in this project are as follows:

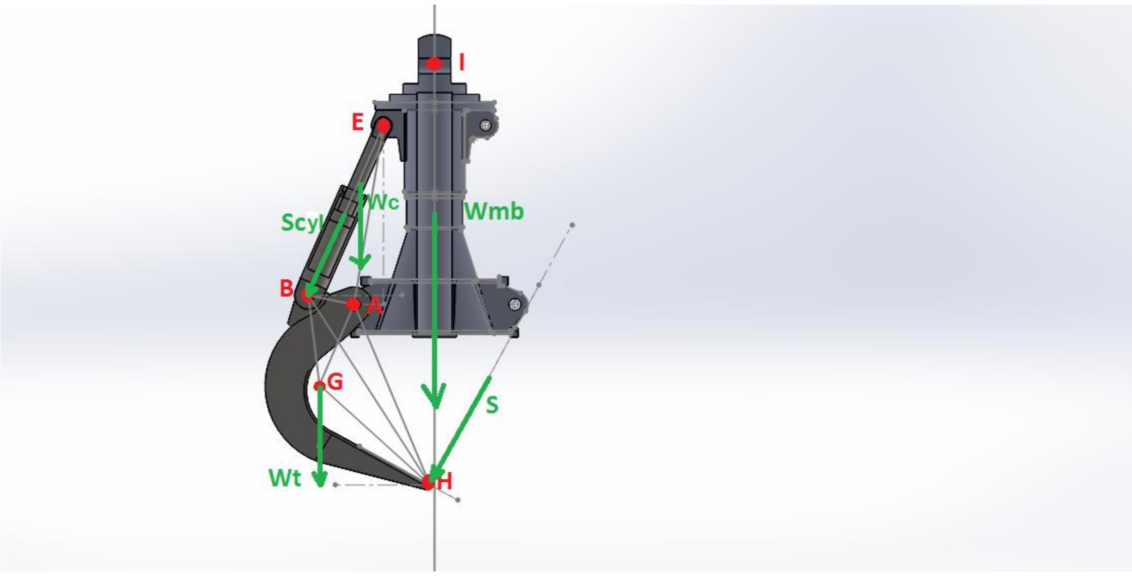


Figure 20: forces

Wt is the weight of the tong.

$$Wt = 126.27767\ kg * 9.8\frac{m}{s^2} = 1237.5\ N$$

Wc is the weight of the cylinder.

$$Wc = 22.78713\ kg * 9.8\frac{m}{s^2} = 223.314\ N$$

Wmb is the weight of the main body.

$$Wmb = 363.008\ kg * 9.8\frac{m}{s^2} = 3557.5\ N$$

S is the reaction of the scrap metal on the tong, normal to its surface.

S has been placed at the end of the tong because it is the most unfavorable point, since it is farther from the fixed point A and will create a bigger moment.

It is important to notice that this reaction is caused by the vertical component of the weight (gravity force) of the scrap metal (with mass M).

"Wscrap" is the part of this scrap metal weight allotted to each of the 4 peels in the distribution of the scrap weight among them.

The reaction S will be such that its vertical component equals that Wscrap force (and its horizontal component will be cancelled by the one of the opposite peel). So, it will depend on the opening of the peel, and its value will be:

$$Wscrap = \frac{M\ kg * 9.8\frac{m}{s^2}}{4\ peels}$$

$$S = \frac{Wscrap}{\cos{(\omega)}}$$

Scyl is the force that the cylinder makes over the peel. This is our first important unknown value.

The masses have been calculated with the software SolidWorks building the elements with the chosen alloy steel.

In the general case, a friction force between the tong and the load would also appear, which would have to be taken into account. It would act on the tong in the direction of steepest descent over its surface.

This friction force would produce a moment opposed to the one from the normal force, which, therefore, would reduce the required cylinder force for equilibrium, especially when the peel is very open. This way, the friction force would effectively help to lift the load.

The following figure illustrates this friction force:

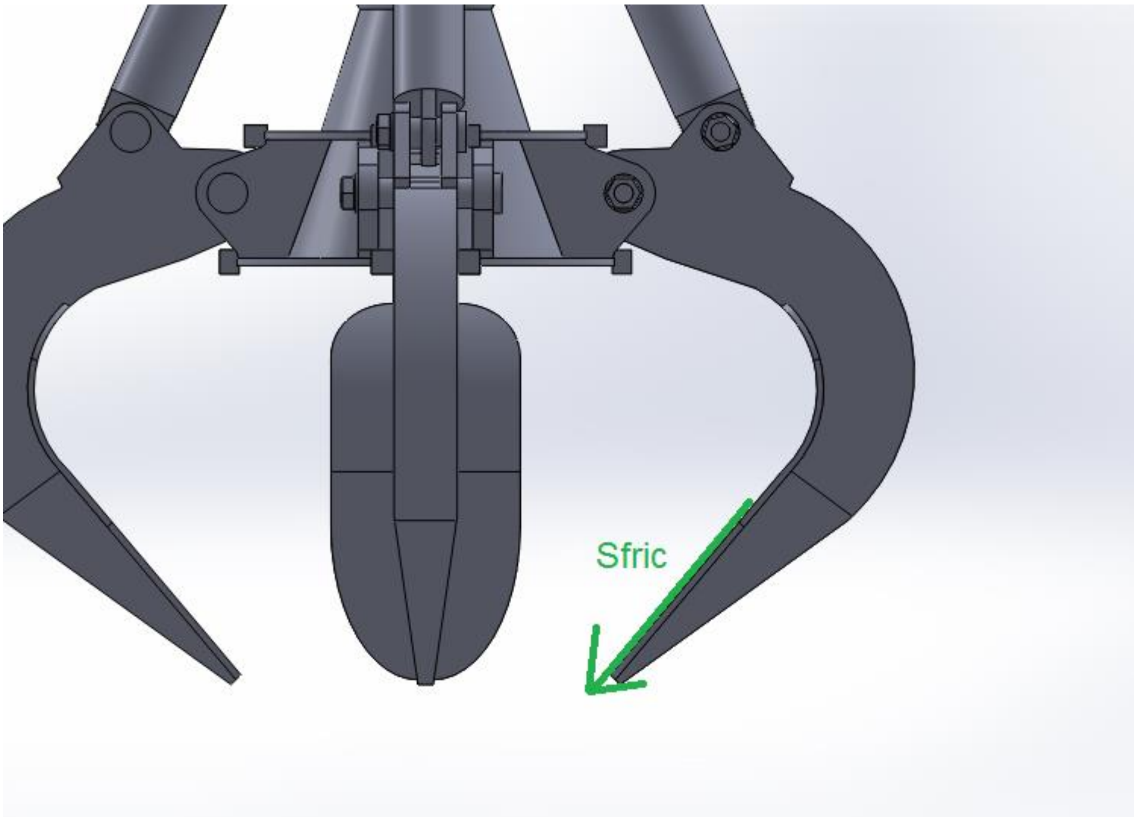


Figure 21: Friction force

This Sfric force would be calculated as:

$$Sfric = \mu * S$$

Where

μ is a friction constant that depends on the relation between the peel material and the load material.

S is the force of the load on the peel, normal to its surface.

However, in this project, we are going to study the worst case, without the friction force help, which is the most realistic case when the load is scrap material, which may have a very low friction constant.

ANGLES:

Six angles have been defined in this model. Two of them are fixed (β and γ) and known from the geometry.

Angles α, ε, θ and ω depend on the position of the tong. Using trigonometry, ε, θ and ω can be defined with α. We will explain this process in the next chapters.

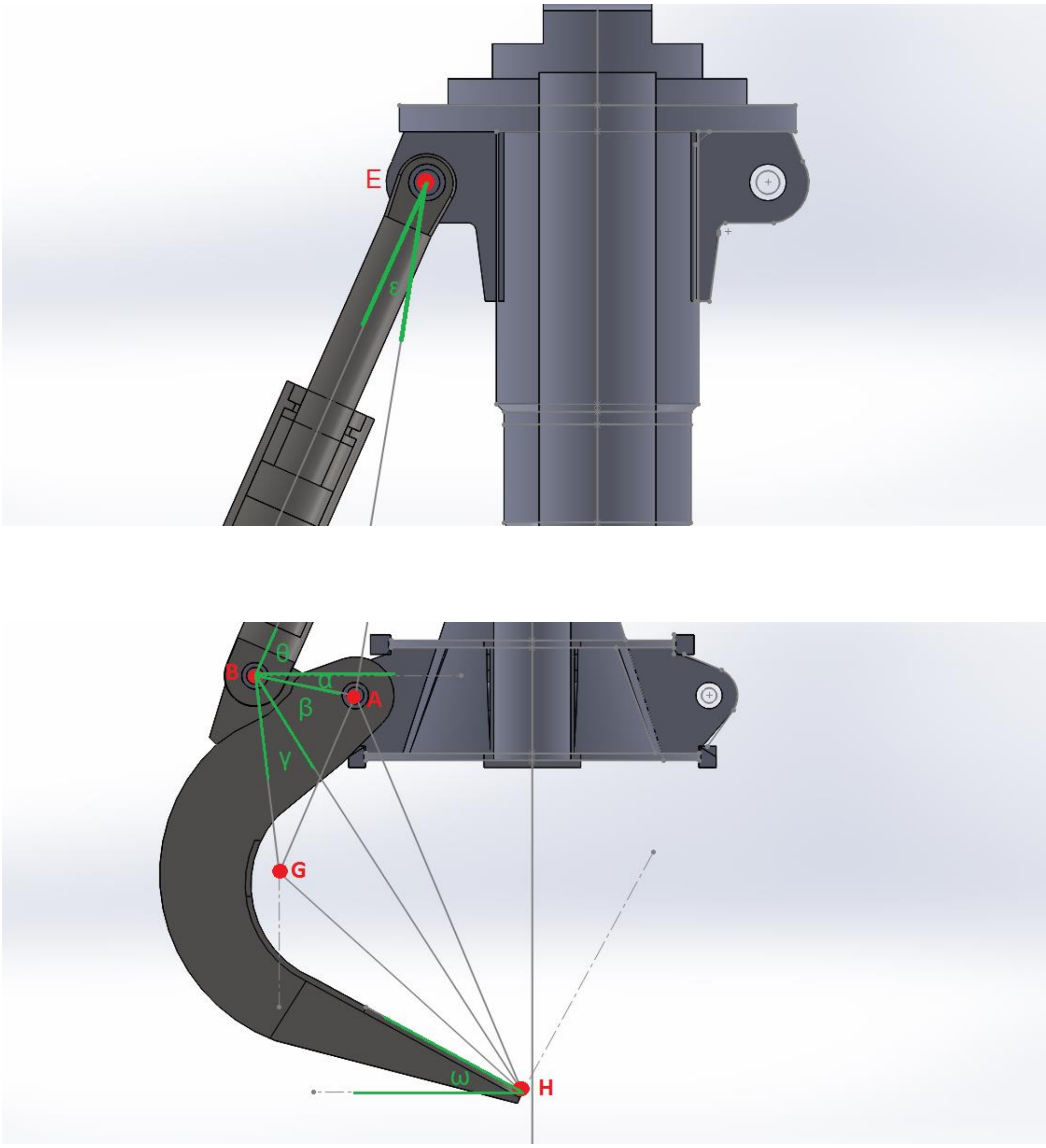


Figure 22: Angles

$$\beta = 46.16º$$

$$\gamma = 25.69º$$

Thanks to the design, we can measure the initial values of angles of α and ω, α_0 and ω_0, that we will later need. We are going to take this closed position as the basis for our calculations.

$$\alpha_0 = 11.10º$$

$$\omega_0 = 28.61º$$

DISTANCES:

There are 7 "point-point" distances that keep constant during the project and their value is known from the design. These constant distances are:

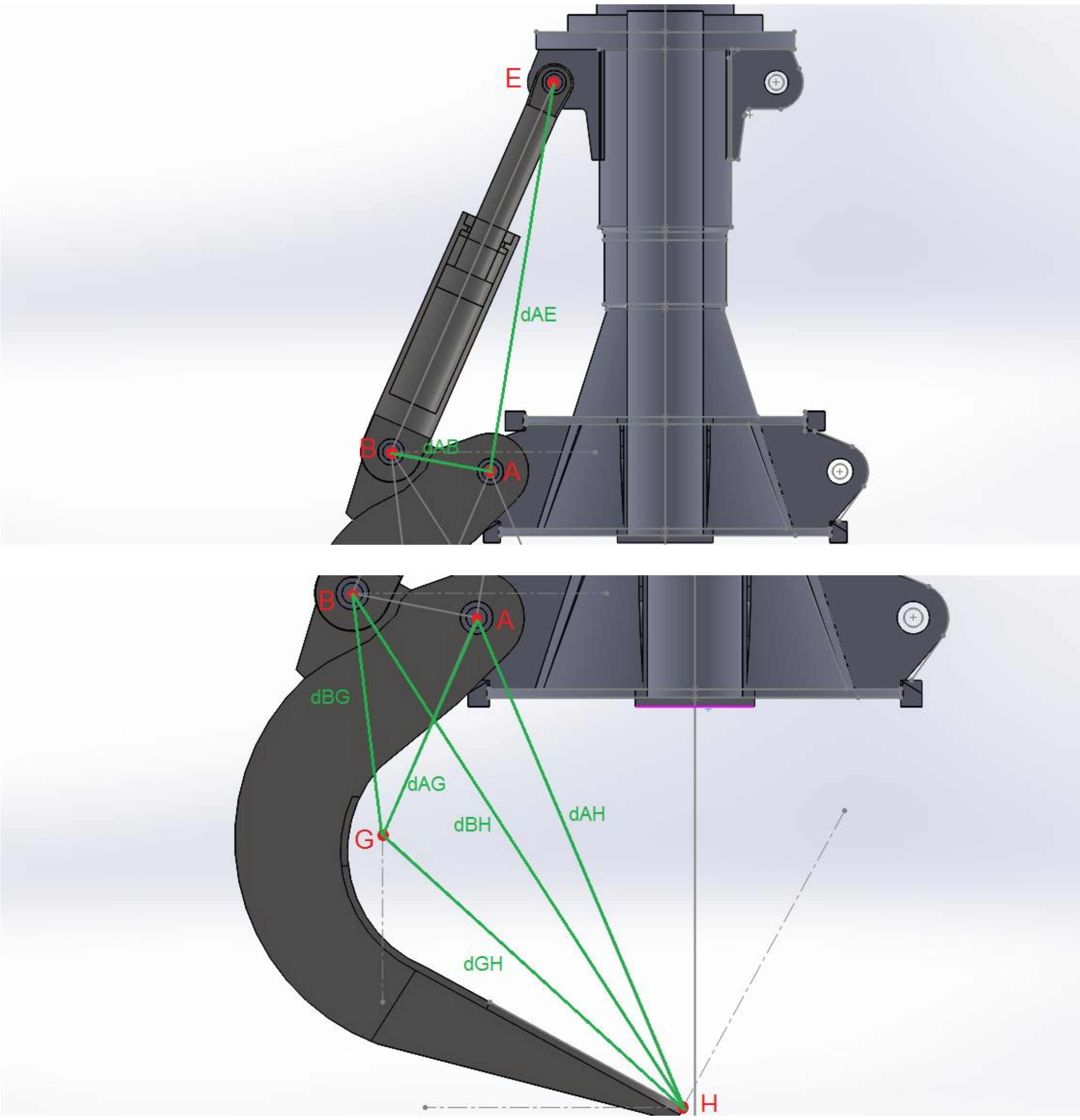


Figure 23: Distances between points

The distance values are:

$$dAB = 0.18195\ m$$

$$dAE = 0.7081\ m$$

$$dAG = 0.34222\ m$$

$$dAH = 0.76441\, m$$

$$dBG = 0.35201\, m$$

$$dBH = 0.87908\, m$$

$$dGH = 0.58222\, m$$

There are 4 "point-force" distances that we will use to do the calculations. Three of them will depend on the angle variable α and the other one, dBH, will not change.

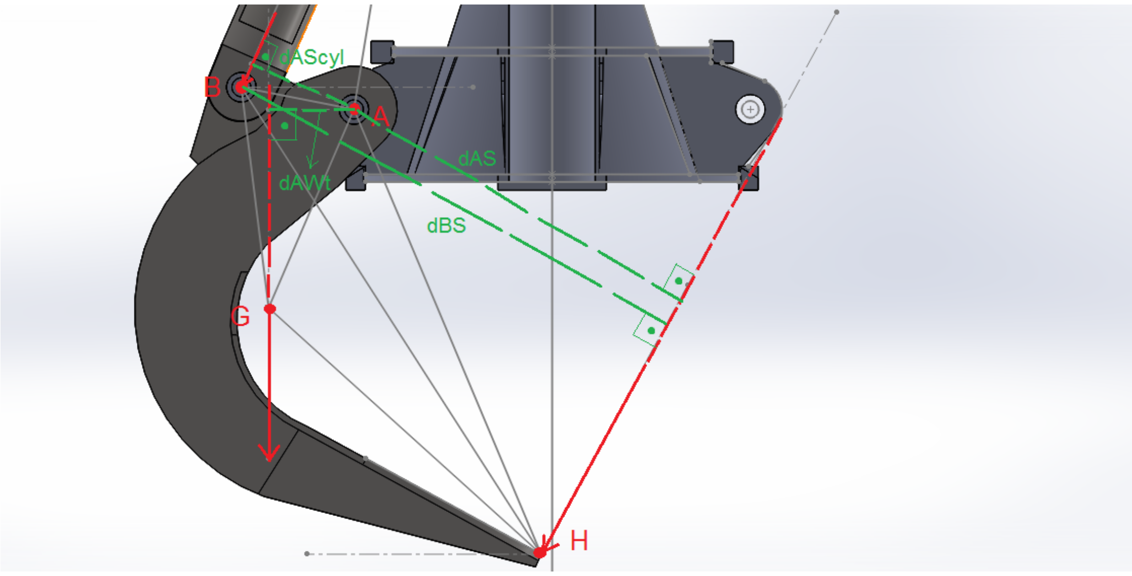


Figure 24: Distances "Point-Force"

dAWt is the distance from point A to Wt, being perpendicular to the direction of Wt.

dAS is the distance from point A to S, being perpendicular to the direction of S.

dAScyl is the distance from point A to Scyl, being perpendicular to the direction of Scyl.

dBS is the distance from B to S, being perpendicular to the line of S and is calculated with the initial angles α_0 and ω_0, that are the angles α and ω in the closed position (initial position).

We analyzed the model only with one tong. Instead of the whole weight of scrap metal, we consider that only the distributed fourth part is applied, because of symmetry of revolution.

5.2. POSITIONS FOR THE CALCULATION.

We are going to do our calculation depending on the value of the angle α, which will give us the value of the force of the cylinder that we need to continue with the rest of calculations.

We are going to show three positions of the angle α (although we are going to analyze the entire opening range, from closed to fully open).

<u>CLOSED PEELS</u> ($\alpha = \alpha_0 = 11.10º$)

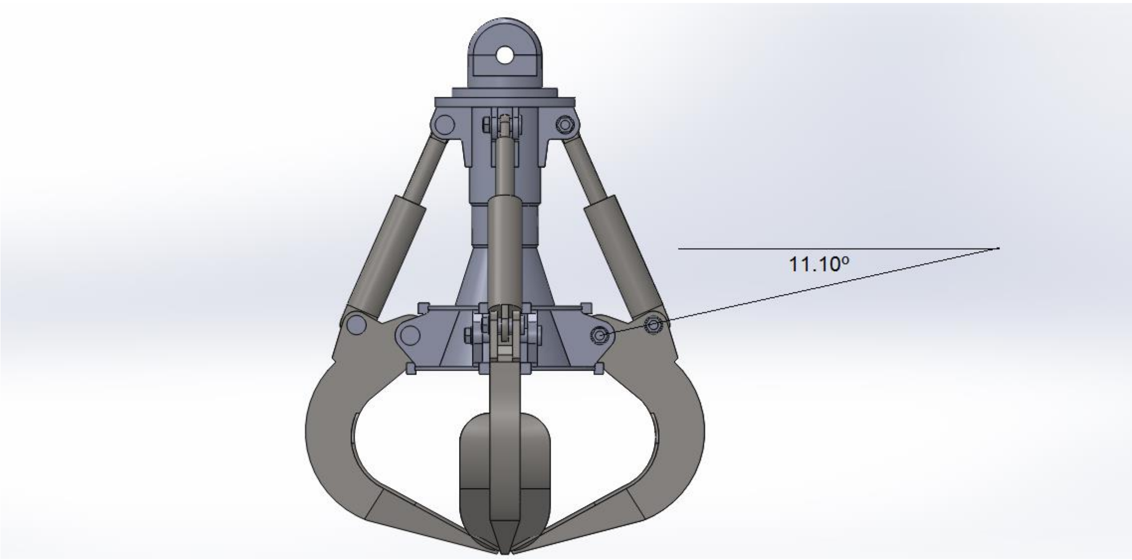


Figure 25: Closed peels position

<u>HALF-OPEN PEELS</u> ($\alpha = 39.75º$)

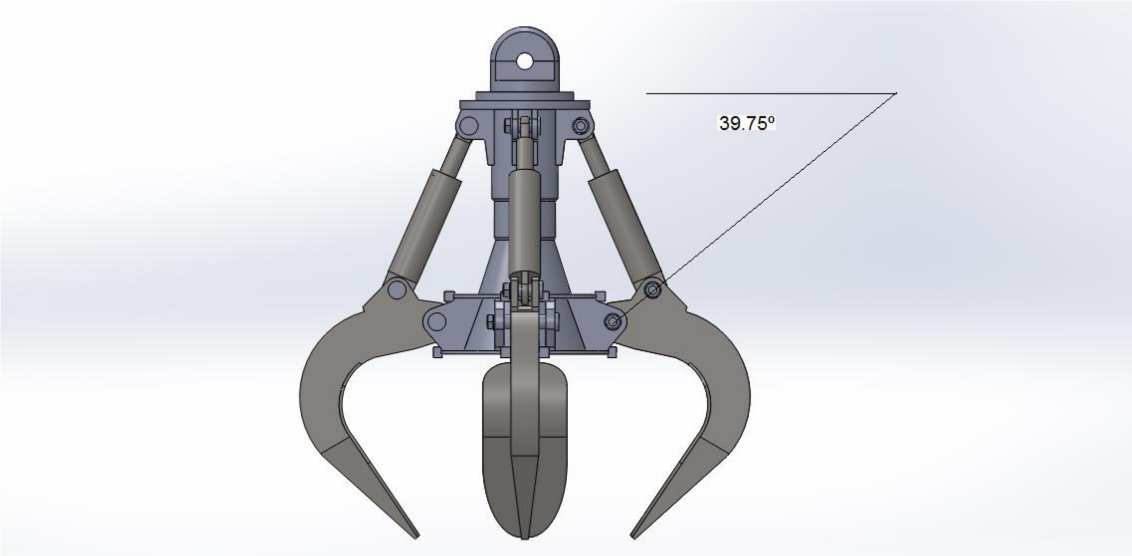


Figure 26: Half-open peels position

<u>OPEN PEELS</u> (α = 68.40º)

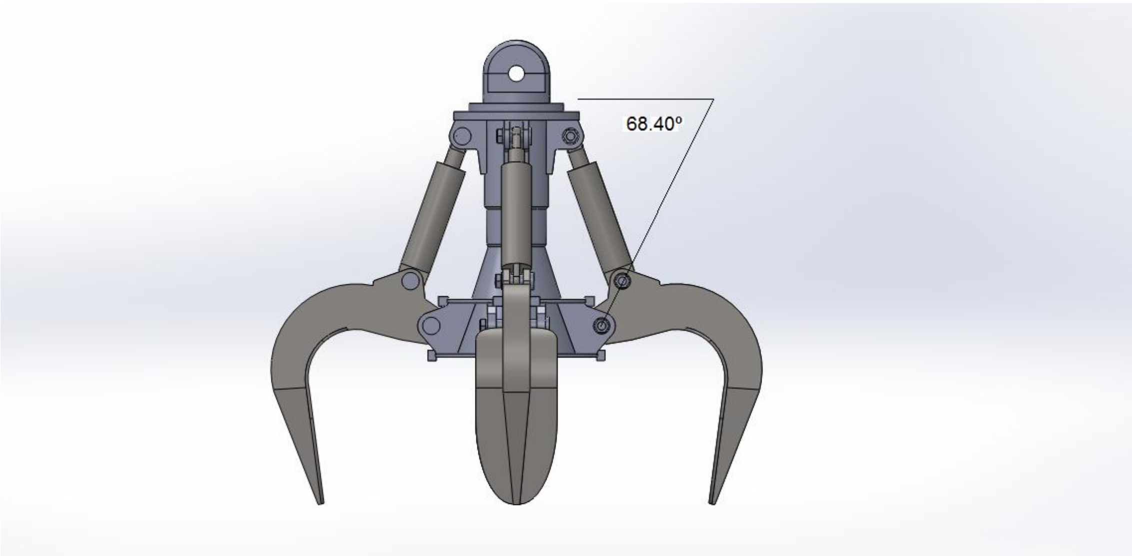


Figure 27: Open peels position

So the range of α is (11.10º < α < 68.40º)

5.3 CALCULATION ON THE TONG

5.3.1 FORCES ON THE TONG

This is the most complex part of the calculations because it involves lot of distances, angles and forces depending only on α angle.

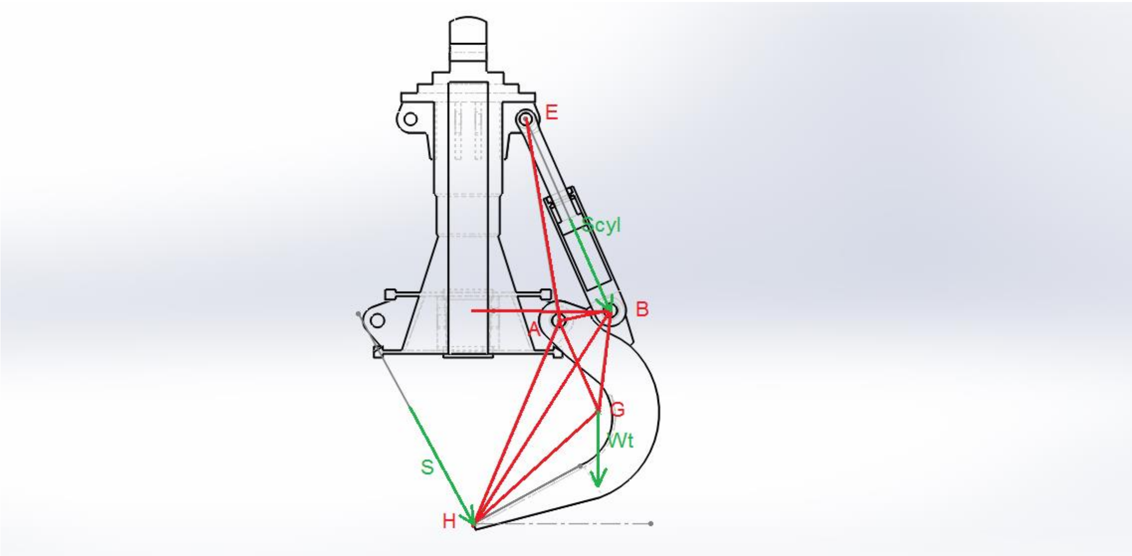


Figure 28: Working model

In order to make the draw clearer, we are going to work only with the necessary lines, that we extract in the following figure:

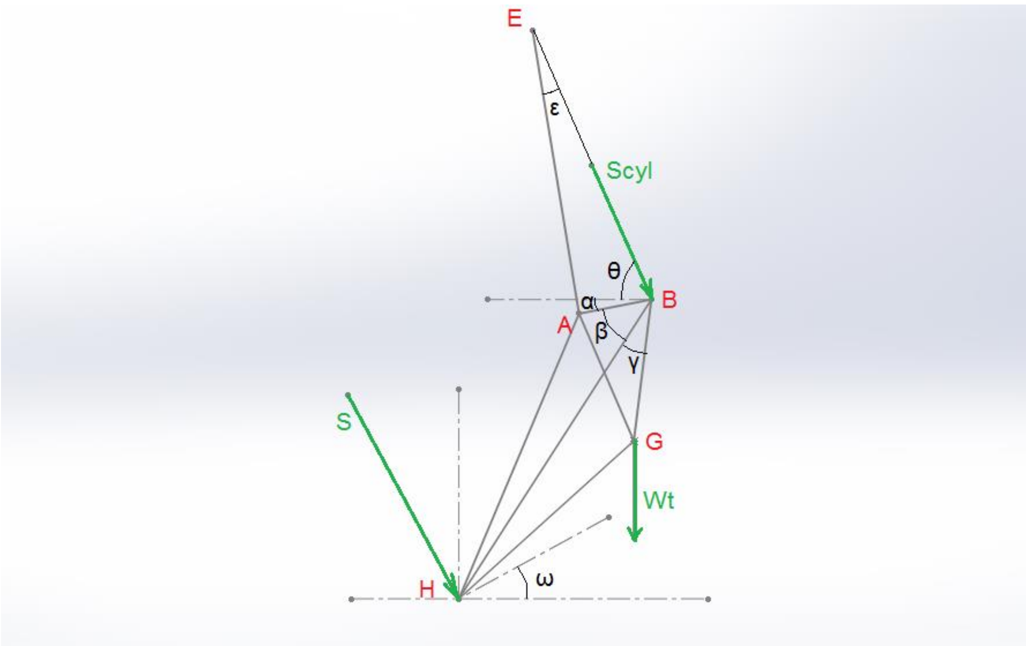


Figure 29: Simplification of the working model

As we said before, we are going to calculate the value of the force of the cylinder Scyl by imposing the condition of null sum of moments at equilibrium. So we are going to do the sum of moments with respect to the point A:

$$Scyl * dAScyl + Wt * dAWt - S * dAS = 0$$

We need now to calculate the distances:

$$dAWt = dAB * \cos(\alpha) - dBG * \cos(\alpha + \beta + \gamma)$$

$$dAS = dBH * \cos(\alpha + \beta - \omega) - dAB * \cos(\omega - \alpha)$$

$$dAScyl = dAB * \sin(\alpha + \theta)$$

To solve for these distances as a function of α, we have to write θ and ω depending only on α.

In order to relate ω with α we are going to define the constant distance dBS. For this purpose, we will use the angles α_0 and ω_0 of the initial position:

$$dBS = dBH * \cos(\alpha_0 + \beta - \omega_0)$$

$$dBS = 0.7714\, m$$

With the previous equation, we can now relate these two angles:

$$\omega = \alpha + \beta - \operatorname{acos}\left(\frac{dBS}{dBH}\right)$$

The next step is to relate θ with α using the auxiliary angle ε.

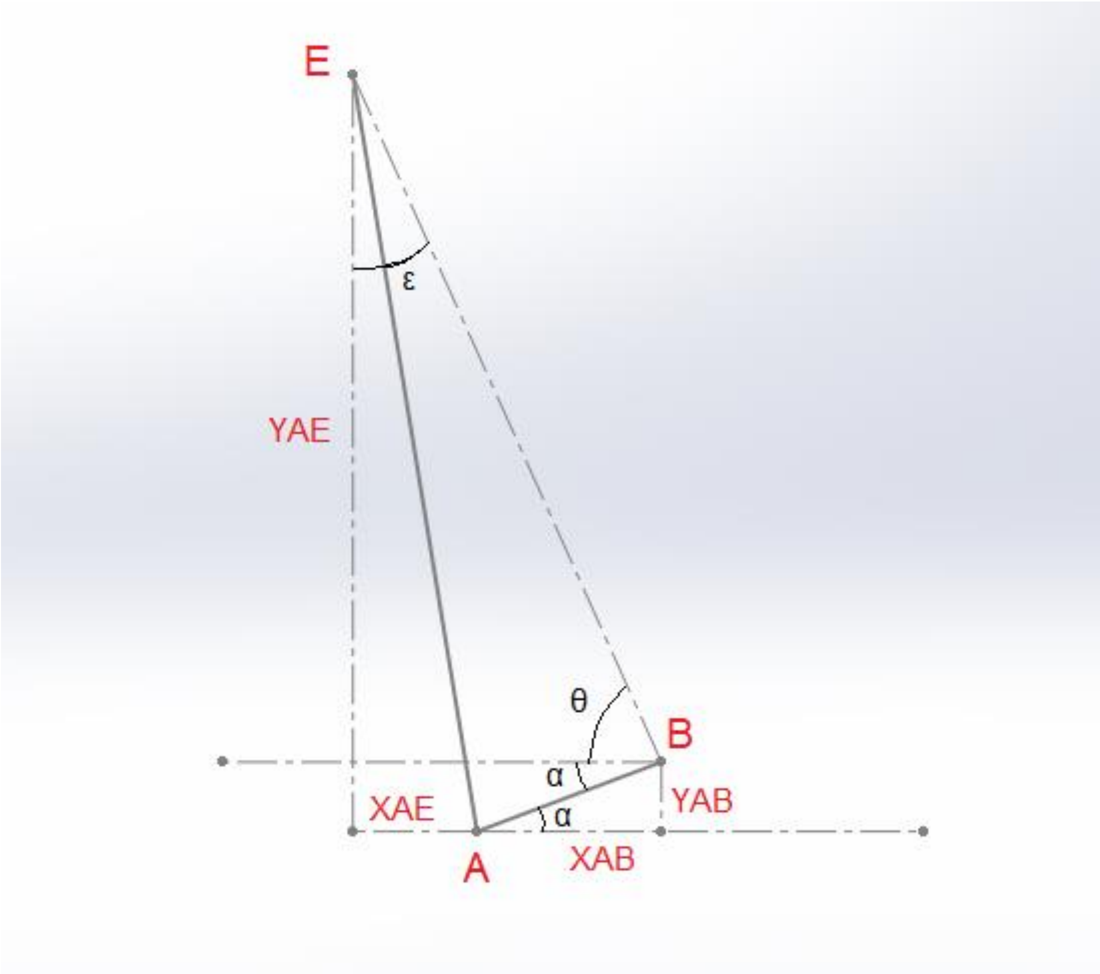


Figure 30: Scheme for calculating θ

XAE and YAE are fixed values which we can get from the design of the model:

$$XAE = 0.11459\ m$$

$$YAE = 0.69877\ m$$

On the other hand, XAB and YAB are going to change depending on the angle α.

$$XAB = dAB * \cos(\alpha)$$

$$YAB = dAB * \sin(\alpha)$$

$$Tg(\varepsilon) = \frac{XAB + XAE}{YAE - YAB}$$

$$\varepsilon = aTg\left(\frac{XAB + XAE}{YAE - YAB}\right)$$

$$\theta = 180º - 90º - \varepsilon$$

Now, we have the equation of sum of moments with respect to point A depending only on α and the mass of the scrap, which will be data that we will introduce.

5.3.2 REACTIONS ON THE TONG

In order to calculate the reactions on the peel, it is enough to take equilibrium of vertical and horizontal forces. There will be two points where we have to get the reactions:

POINT A

$$VA = Wscrap + Wt + Scyl * \sin(\theta)$$

$$HA = Scyl * cos(\theta) + S * sin(\omega)$$

POINT B

$$VB = Scyl * \sin(\theta)$$

$$HB = Scyl * \cos(\theta)$$

5.4 CALCULATION ON THE CYLINDER

Calculations on the cylinder are easier, because the forces come directly from the tong and we only have to add the contribution of the weight of the cylinder.

5.4.1 FORCES ON THE CYLINDER

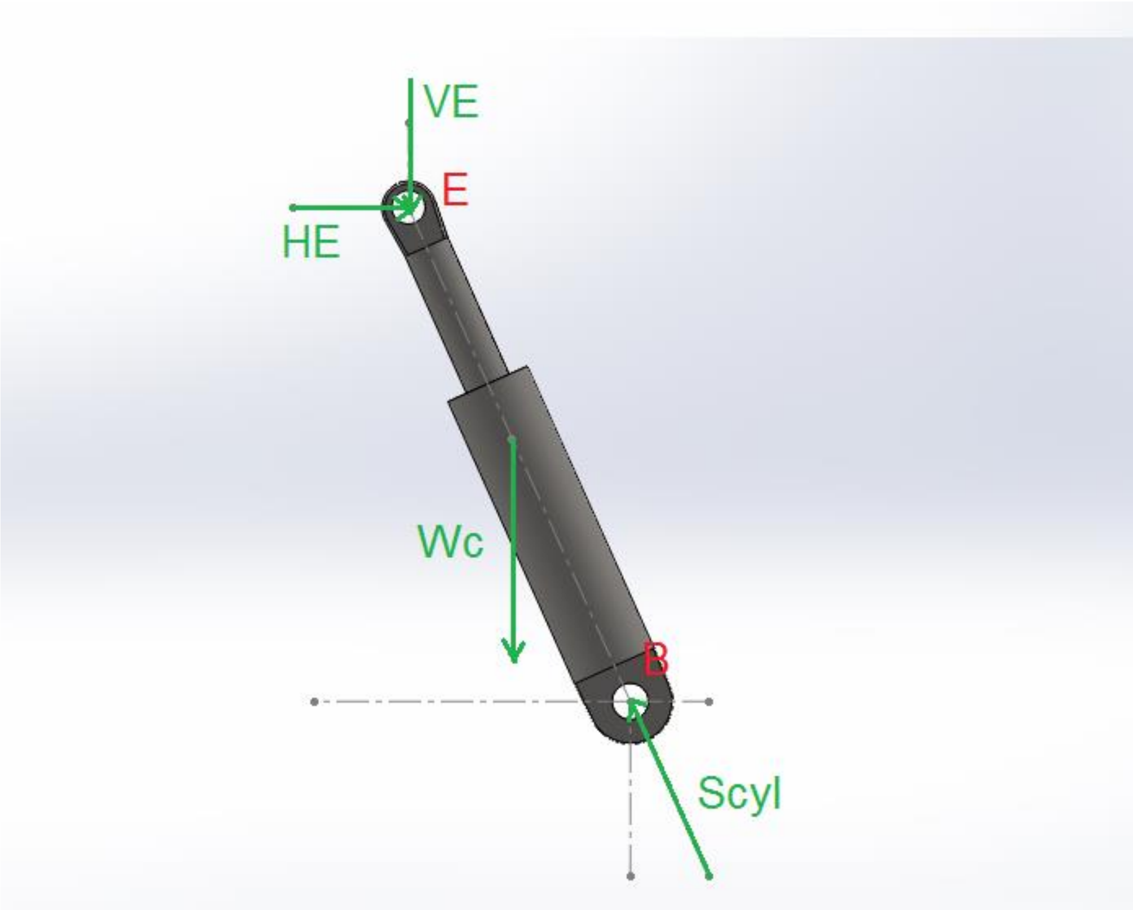


Figure 31: Forces on the cylinder

The new component we have is the weight of the cylinder Wc.

5.4.2 REACTIONS ON THE CYLINDER

With equilibrium of vertical and horizontal forces:

$$VE = VB - Wc$$

$$HE = HB$$

VB and HB have the same value as in the tong.

5.5 CALCULATION ON THE MAIN BODY

Now that we already have the information about the peels and the cylinders, the reactions on the points A and E are trivial.

The horizontal reactions on A and E are radial and because of the symmetry of revolution, one radial reaction is counteracted with its opposite. So, for this theoretical analysis, these reactions are unnecessary. But later, when we have to calculate the behavior of the model with the computer software SolidWorks, it will be necessary to include them.

With the vertical reactions and the weight of the main body of the model, we will be able to calculate the reactions on the point of the top, I.

5.5.1 FORCES ON THE MAIN BODY

As we just said, it is only necessary to add the weight of the main body:

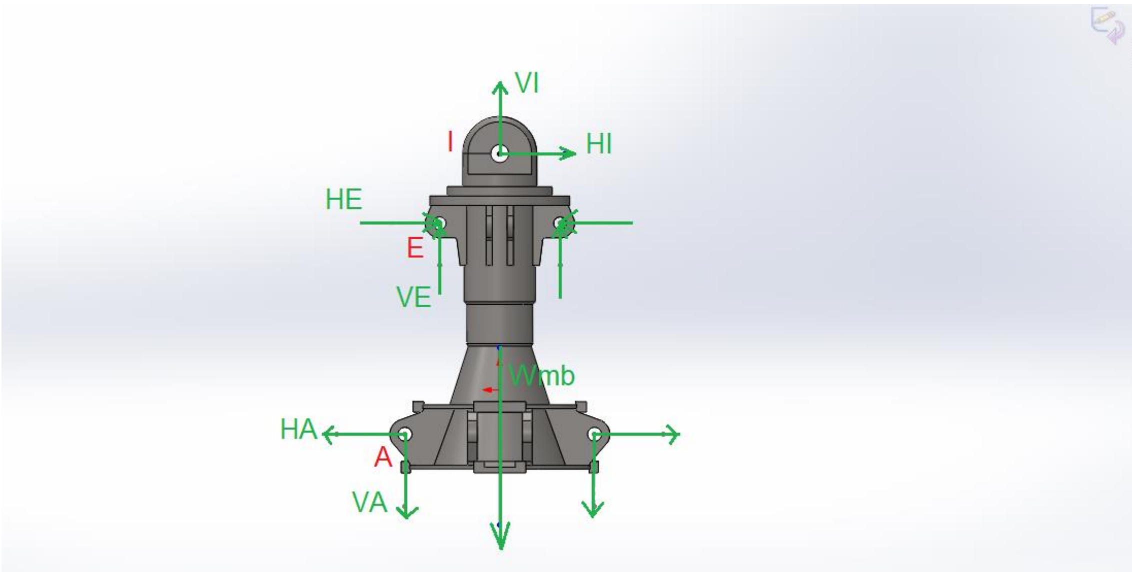


Figure 32: Forces on the main body

5.5.2 REACTIONS ON THE MAIN BODY

As we can see, and because of symmetry, horizontal reactions are canceled. Therefore, we can deduce that:

$$HI = 0$$

From the equilibrium of vertical forces:

$$VI = Wmb + 4 * VA - 4 * VE$$

VA and HA have the same value as on the tong.

VE and HE have the same value as on the cylinder.

5.6. RESULTS

When we have the vertical and horizontal components of a reaction, we will be able to calculate the total reaction in this way:

$$R = \sqrt{V^2 + H^2}$$

5.6.1. RESULTS ON THE TONG

Plotting Scyl (N) vs. angle (grades):

780 kg

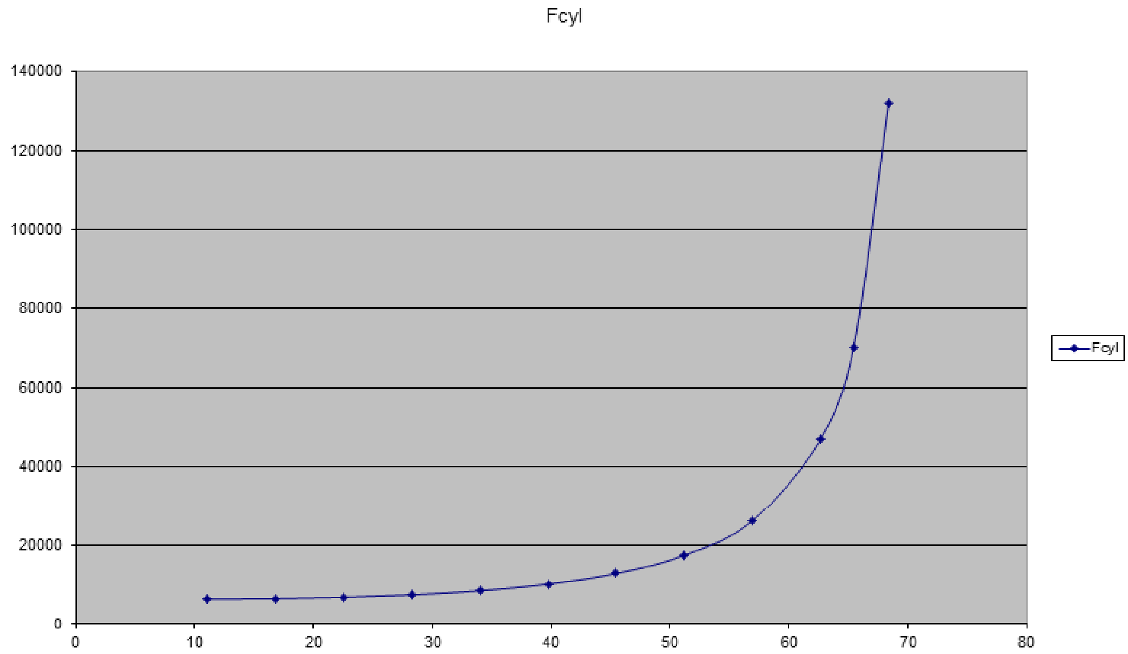


Figure 33: Scyl (N) vs Angle (grades) for 780 kg load

We can see that the most unfavorable case is when the grapple is fully open, i.e., at 68.40º.

By knowing this angle, we can introduce it in the previous equations and obtain the force on the cylinder:

$$\underline{\boldsymbol{Scyl = 131821.845\ N}}$$

With this value and the previous calculation we can get the following reactions:

POINT A

$$VA = 127990\ N$$

$$HA = 69527\ N$$

$$RA = 145655.223\ N$$

POINT B

$$VB = 124840N$$

$$HB = 42802\ N$$

$$RB = 131821.845\ N$$

5.6.2 RESULTS ON THE CYLINDER

POINT B

$$VB = 124840\ N$$

$$HB = 42802\ N$$

$$RB = 131821.845\ N$$

POINT E

$$VE = 124620\ N$$

$$HE = 42802\ N$$

$$RE = 131765.533\ N$$

5.6.3 RESULTS ON THE MAIN BODY

POINT I

$$VI = 17045\ N$$

$$HI = 0\ N$$

$$RI = 17045\ N$$

POINT A

$$VA = 127990\ N$$

$$HA = 69527\ N$$

$$RA = 145655.223\ N$$

POINT E

$$VE = 124620\ N$$

$$HE = 42802\ N$$

$$RE = 131765.533\ N$$

6. ANALYSIS WITH A CAD PROGRAM

CAD (Computer Aided Design) is the use of computer systems to assist in the creation, modification, analysis or optimization of a design.

CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing.

It is possible to apply geometric, cinematic or material properties, for instance, to these designs.

There are several different packages of CAD software in the market such as AutoCAD, CATIA, SolidWorks or SolidEdge.

6.1 SOLIDWORKS

SolidWorks is a 3D mechanical CAD program for “Microsoft Windows” and is being developed by “Dassault Systemes SolidWorks Corp”, a subsidiary of “Dassault Systemes, S.A”.

SolidWorks is a Parasolid-based solid modeler, and utilizes a “parametric feature-based” approach to create models and assemblies. The program allows the user to model parts and assemblies and extract drawings and other kind of documentation for manufacturing.

SolidWorks provides a suite of product development tools mechanical design, design verification, data management, and communication tools. SolidWorks Premium includes all the capabilities of SolidWorks Professional as well as routing and analysis tools, including SolidWorks Routing, SolidWorks Simulation (described in the next part), and SolidWorks Motion.

It is currently used by over 2 million engineers and designers in more than 165000 companies worldwide.

Figure 34: SolidWorks logo

6.1.1 SOLIDWORKS SIMULATION

SolidWorks Simulation is a design validation tool that shows engineers how their designs will behave as physical objects.

SolidWorks Simulation provides core simulation tools to test the user's designs and take the decisions to improve quality.

The full integration creates a short learning curve and eliminates the redundant tasks required with traditional analysis tools.

Component materials, connections, and relationships defined during design development are fully understood for simulation. Products can be tested for force and safety, and the kinematics fully analyzed.

6.2 CREATION OF THE MODEL WITH SOLIDWORKS

Once we have all the elements designed with SolidWorks (Presented in the points 4 and 10), we can proceed to perform the study with SolidWorks Simulation.

Since the program doesn't let the user do the simulation with the entire assembly, we will have to do it piece by piece.

In order to perform the study of the most important elements, it is necessary to follow the next steps:

- Define the type of study: We will do a static study. In this study, we apply some loads and, in order to keep the equilibrium, some reactions will appear.

- Define the material and its properties: As we said before, the material we have chosen is an Alloy steel. SolidWorks has its own library of materials and it provides the properties of the selected material.

- Establish the restrictions of the movement: We have supposed, for analyzing these elements, that one part of them is completely restricted.

- Establish the forces that perform on each element defining their magnitude, direction and sense. It is necessary to define these three parts of a force, but it is necessary also to indicate if the force will be performed on a plane, along a line or at a point.

- Define the mesh: We can choose between a thin mesh or a thick mesh. The thin mesh provides more accurate information, but if we have a big model with a lot of loads, SolidWorks will take a lot time to calculate the model.

- Execute the simulation: This indicates to the program that we are going to start our study, and it will apply the previous step to run this study.

- Obtain the results: After some time executing the study, SolidWorks will provide us with a very detailed information about stress, displacement, strain and so on.

6.3 ANALYSIS OF THE MODEL WITH SOLIDWORKS

The SolidWorks analysis has been elaborated in the most unfavorable situation. This situation is, as we said before:

$$Scyl = 131821.845\ N$$

$$\alpha = 86.40º$$

$$\omega = 85.91º$$

We have shown the value of ω because it will be necessary in order to apply the gravity to the model in the tong.

Discussions about the analysis on SolidWorks will be explained in the point 8 (Conclusions).

6.3.1 ANALYSIS OF THE TONG

In order to analyze the tong, we decided to fix the point that joins the tong with the main body.

We have established the gravity plane with the angle ω corresponding to the most unfavorable position.

We have applied the forces of the hydraulic cylinder (at the point that joins the tong with the cylinder). But in the model, this point is separated in two parts, so we have to apply half of the force to each part. The force of the load has been also applied on the edge below.

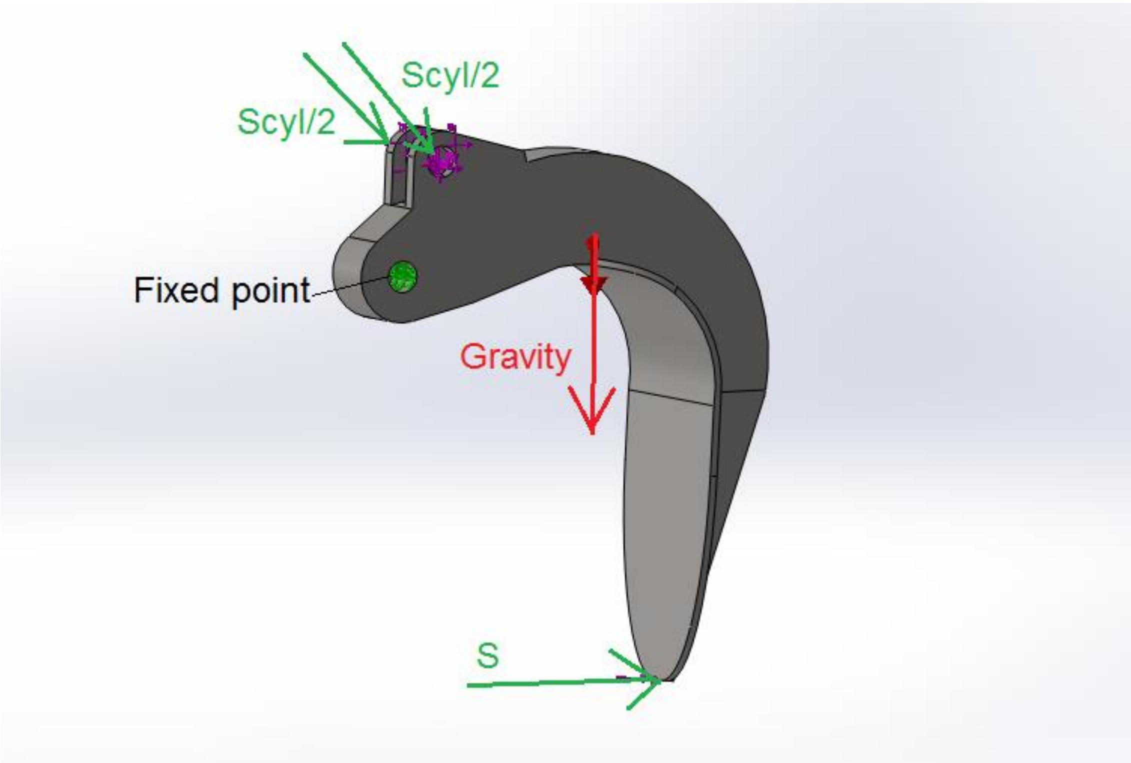
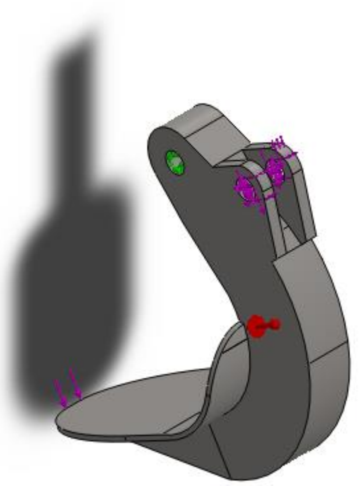
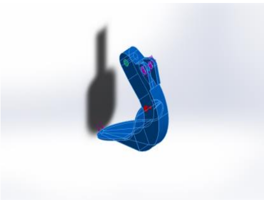


Figure 35: Tong simulation

Model information



Name of the model: tong

Solids			
Name and reference document	Treaty as	Volumetric properties	Path to document / Date modified
Simetría1 	Solid	**Mass**:126.278 kg **Volume**:0.0163997 m^3 **Density**:7700 kg/m^3 **Weight**:1237.52 N	C:\Users\Juan\Desktop\PROYECTO\pinza.SLDPRT Jun 17 23:52:41 2013

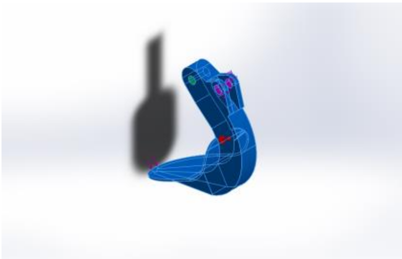
Study properties

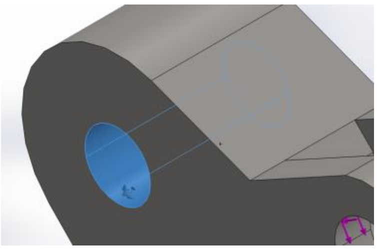
Name of the study	Tong
Analysis type	Static
Mesh type	Solid mesh
Calculate free body forces	Activate
Results folder	Documento de SolidWorks (C:\Users\Juan\Desktop\PROYECTO)

Units

Units system	Metric
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material properties

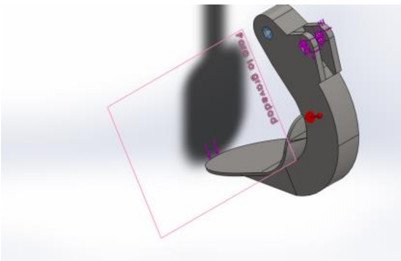
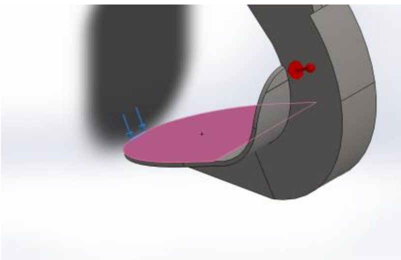
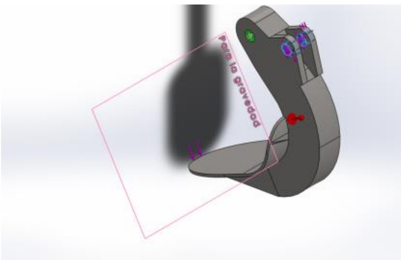
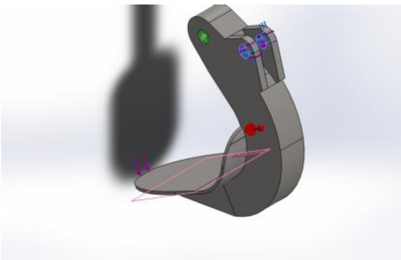
Model reference	Properties
	Name: Alloy Steel Model type: Isotropic elastic lineal Yield limit: 6.20422e+008 N/m^2 Tensile strength: 7.23826e+008 N/m^2 Modulus of elasticity: 2.1e+011 N/m^2 Poisson coefficient: 0.28 Density: 7700 kg/m^3

Clamping name	Clamping picture	Clamping details
Fixed-1		Entities: 1 face(s) Type: Fixed geometry

Resulting forces

Component	X	Y	Z	Resulting
Reaction force(N)	72117	126548	-0.954964	145655
Reaction moment(N-m)	0	0	0	0

Loads and Restrains

Load name	Load picture	Load details
Gravity-1		**Reference:** Top view **Values:** 0 0 -9.81 **Units:** SI
Force -1		**Entities:** 1 edge(s) **Reference:** Face< 1 > **Type:** Apply force **Values:** ---, ---, 26793 N
Force -2		**Entities:** 2 face(s), 1 plan(s) **Reference:** Top view **Type:** Apply force **Values:** ---, ---, -62420 N
Force -3		**Entities:** 2 face(s), 1 plan(s) **Reference:** Plan4 **Type:** Apply force **Values:** ---, ---, 21401 N

Mesh information

Mesh type	Solid mesh
Mesher used	Standar mesh
Automatic transition	Desactivate
Include automatic mesh loops	Desactivate
Jacobeans points	4 points
Size of elements	12.7044 mm
Tolerance	0.635219 mm
Mesh quality	Higher order quadratic elements

Mesh information - Details

Total number of nodes	84247
Total number of elements	54653
Maximum aspect ratio	10.813
% of elements with aspect ratio < 3	99.7
% of elementes with aspect ratio > 10	0.00549
% of distorted elements	0
Time to complete de mesh (hh;mm;ss)	00:00:06
Computer name	JUAN-PC

Resulting forces

Reaction forces

Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N	72117	126548	-0.954964	145655

Reaction moments

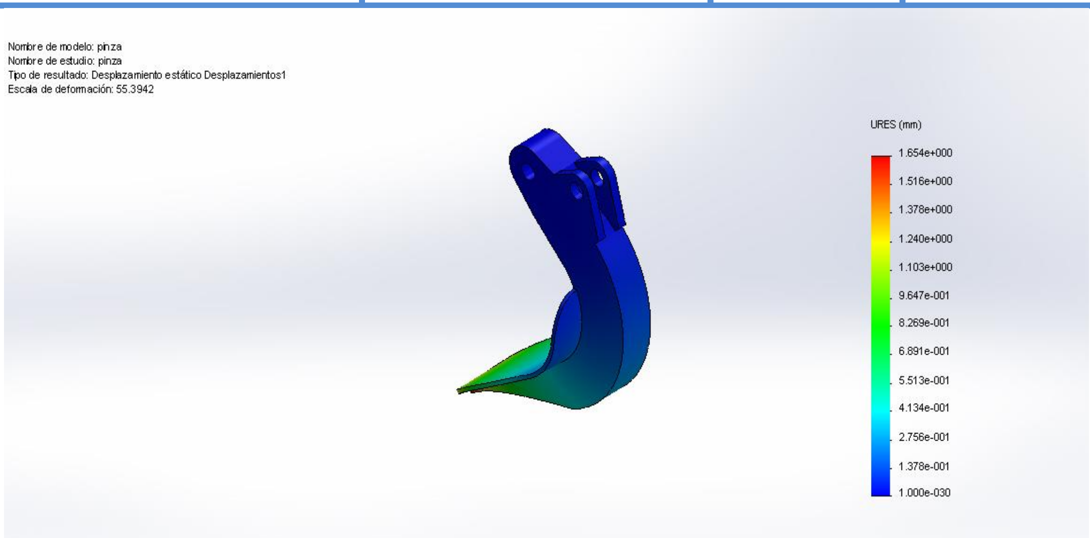
Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N-m	0	0	0	0

Study results

Name	Type	Min.	Max.
Stress1	VON: Von Mises stress	73786.8 N/m^2 Node: 70825	3.15961e+008 N/m^2 Node: 1493

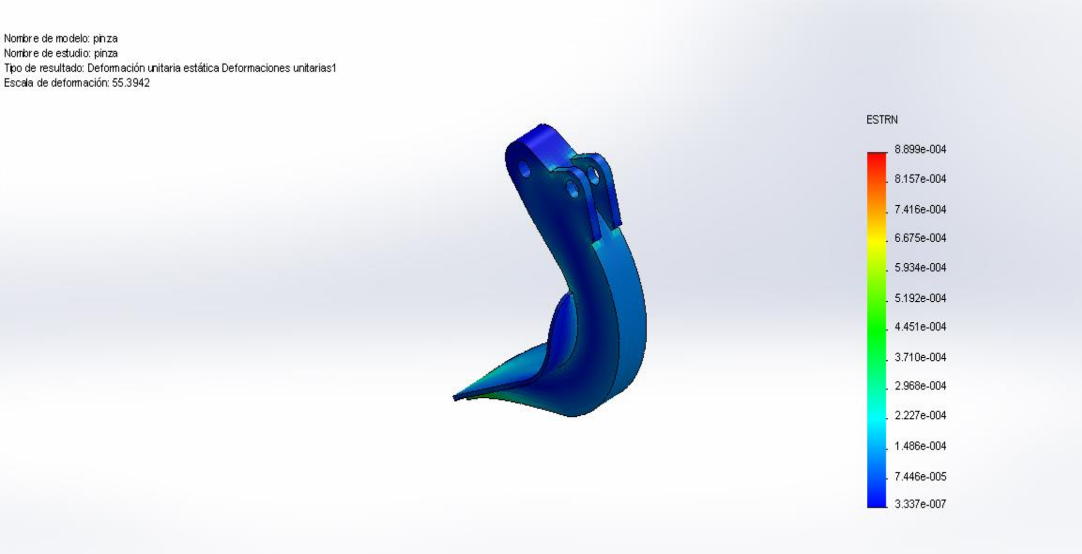
Tong – Stress 1

Name	Type	Min.	Max.
Displacement 1	URES: Resulting displacement	0 mm Node: 1	1.65378 mm Node: 2173



Tong – Displacement 1

Name	Type	Min.	Max
Strain	ESTRN: Equivalent strain	3.33701e-007 Element: 8329	0.000889859 Element: 25303

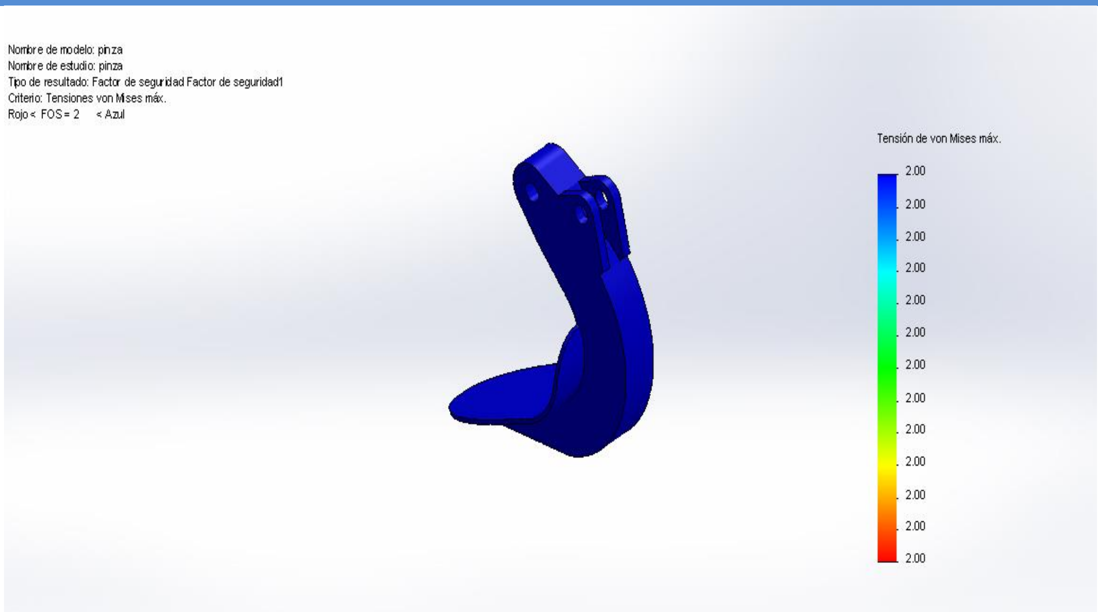


Tong – Strain 1

Name	Type
Displacement 1	Deformed shape

Tong – Displacement 1

Name	Type	Min.	Max
Safety factor 1	Max. Von Mises stress	1.9636 Node: 1493	8408.31 Node: 70825



Tong – Safety factor 1

6.3.2 ANALYSIS OF THE CYLINDER

In this part, we are going to show the two important parts of the hydraulic cylinder at the same time, since the analysis method has been similar. These parts are the sleeve of the cylinder and the piston rod.

We have fixed the joint “cylinder – tong” of the sleeve and the joint “cylinder – main body” of the piston rod.

In both cases, we have applied the force Scyl. On the sleeve, it is exactly the force we have to consider but the force on the piston rod would be a little bit less. For this reason, we haven’t considered the component of gravity on the piston rod, because it is already included on the force Scyl. Gravity on the sleeve is also included in the force we are going to apply.

Anyway, this gravity component involves only the weight of the cylinder that is much lower than the rest of the forces.

This Scyl force has been applied in the longitudinal direction of the cylinder.

Sleeve:

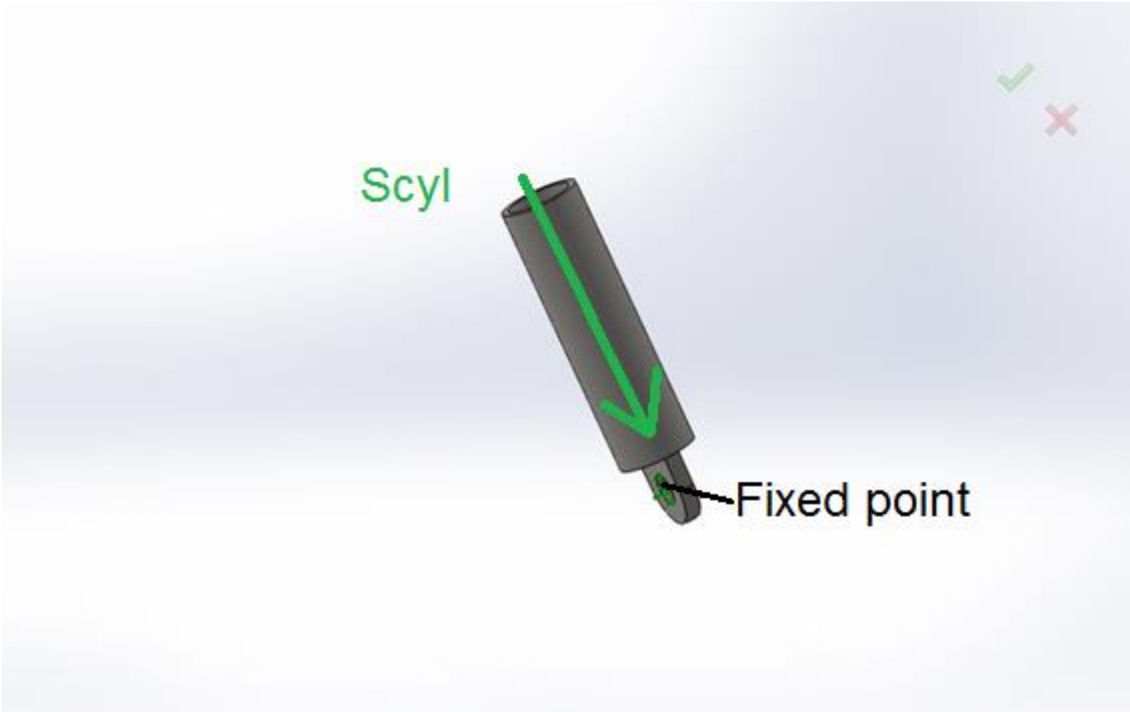


Figure 36: Sleeve simulation

Piston rod:

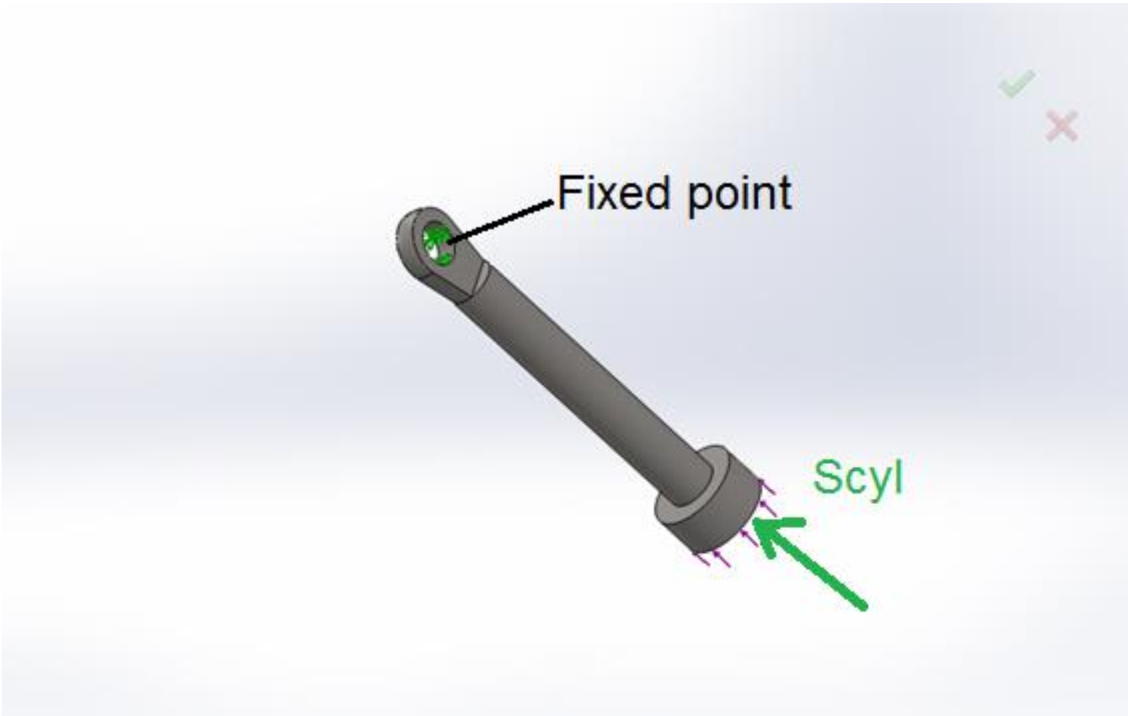
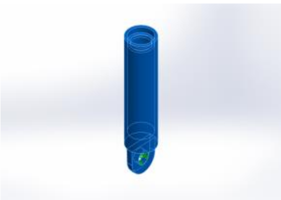


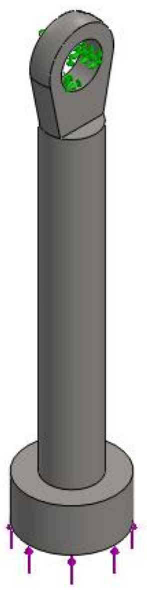
Figure 37: Piston rod simulation

Model information

Name of the model: sleeve

Solid

Name and reference document	Treaty as	Volumetric properties	Path to document / Date modified
Cortar-Extruir2 	Solid	**Mass**:13.7746 kg **Volume**:0.0017889 m^3 **Density**:7700 kg/m^3 **Weight**:134.991 N	C:\Users\Juan\Desktop\PROYECTO\Cilindro Juan\cilindro juan.SLDPRT Jun 18 20:51:24 2013



Name of the model: piston rod

Solid			
Name and reference document	Treaty as	Volumetric properties	Path to document / Date modified
Cortar-Extruir2 	Solid	**Mass**:7.76822 kg **Volume**:0.00100886 m^3 **Density**:7700 kg/m^3 **Weight**:76.1286 N	C:\Users\Juan\Desktop\PROYECTO\Cilindro Juan\vastago juan.SLDPRT Jun 18 20:51:24 2013

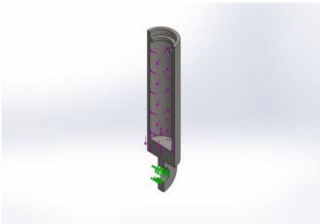
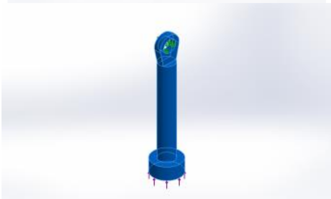
Units

Units system	Métrico (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Study properties

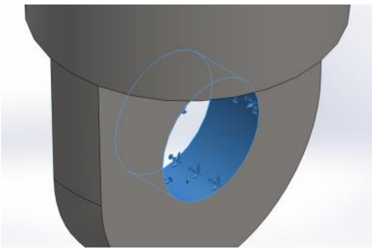
Name of the study	Sleeve/Piston rod
Analysis type	Static
Mesh type	Solid mesh
Calculate free body forces	Activate
Results folder	Documento de SolidWorks (C:\Users\Juan\Desktop\PROYECTO\Cilindro Juan)

Material properties

Model reference	Properties
 	**Name:** Alloy Steel **Model type:** Isotropic elastic lineal **Yield limit:** 6.20422e+008 N/m^2 **Tensile strength:** 7.23826e+008 N/m^2 **Modulus of elasticity:** 2.1e+011 N/m^2 **Poisson coefficient:** 0.28 **Density:** 7700 kg/m^3

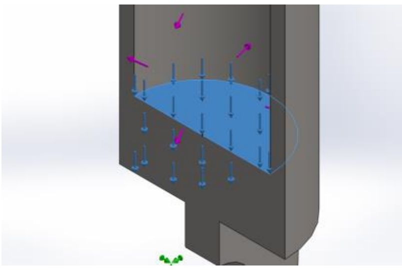
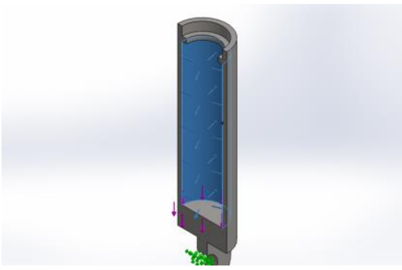
Loads and Restrains

<u>Sleeve</u>

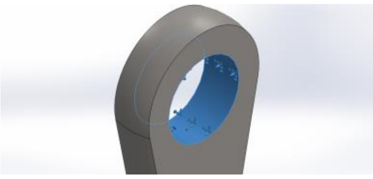
Clamping name	Clamping picture	Clamping details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed geometry

Resulting forces

Component	X	Y	Z	Resulting
Reaction force(N)	**-2.68102**	**131770**	**-1.48007**	**131770**
Reaction moment(N-m)	**0**	**0**	**0**	**0**

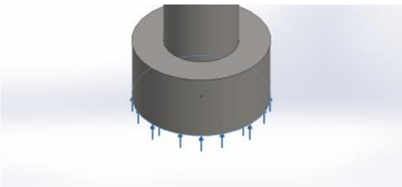
Load name	Load picture	Load details
Force -1		**Entities:** 1 face(s) **Type:** Apply force **Value:** 131822 N
Force -2		**Entities:** 1 face(s) **Type:** Apply force **Value:** 131822 N

Piston rod

Clamping name	Clamping picture	Clamping details
Fixed -1		**Entities:** **1 face(s)** **Type:** **Fixed geometry**

Resulting forces

Component	X	Y	Z	Resulting
Reaction force(N)	**-0.0417544**	**-131791**	**0.99162**	**131791**
Reaction moment(N-m)	**0**	**0**	**0**	**0**

Load name	Load picture	Load details
Force -1		**Entities:** **1 face(s)** **Type:** **Apply force** **Value:** **131822 N**

Mesh information

Mesh type	Solid mesh
Mesher used	Standar mesh
Automatic transition	Desactivate
Include automatic mesh loops	Desactivate
Jacobeans points	4 points
Mesh quality	Higher order quadratic elements

Sleeve

Size of elements	6.07095 mm
Tolerance	0.303548 mm

Piston rod

Size of elements	5.01588 mm
Tolerance	0.250794 mm

Mesh information - Details

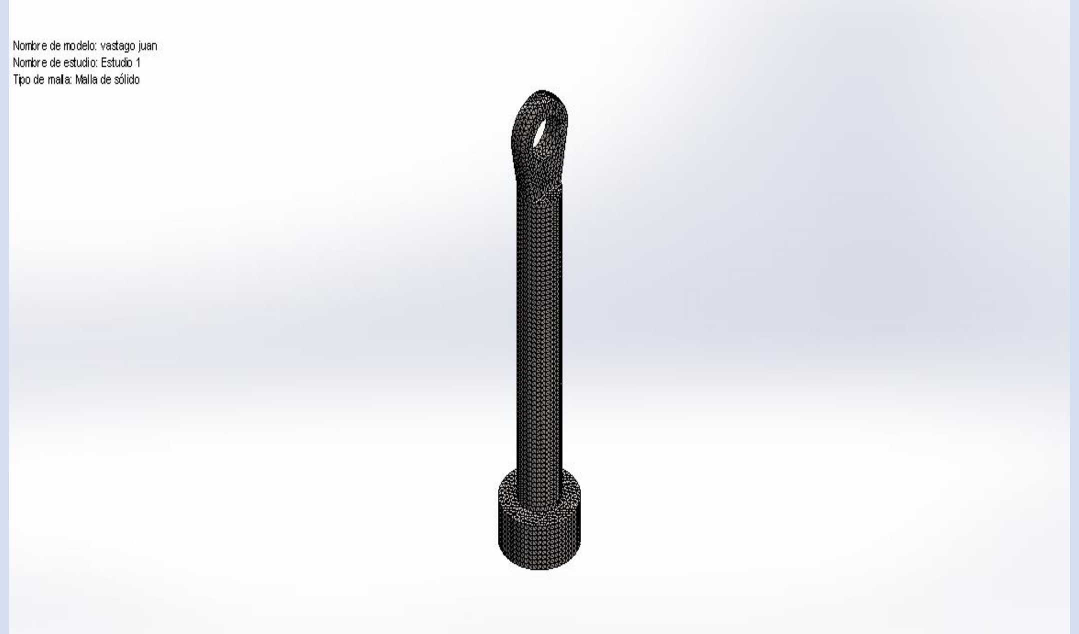
Sleeve

Total number of nodes	89933
Total number of elements	55648
Maximum aspect ratio	5.1656
% of elements with aspect ratio < 3	99.9
% of elementes with aspect ratio > 10	0
% of distorted elements	0
Time to complete de mesh (hh;mm;ss)	00:00:07
Computer name	JUAN-PC


Nombre de modelo: cilindro juan
Nombre de estudio: cilindro
Tipo de malla: Malla de sólido

Piston rod

Total number of nodes	69606
Total number of elements	46815
Maximum aspect ratio	13.09
% of elements with aspect ratio < 3	99.4
% of elementes with aspect ratio > 10	0.00214
% of distorted elements	0
Time to complete de mesh (hh;mm;ss)	00:00:05
Computer name	JUAN-PC



Resulting forces

Reaction forces Sleeve

Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N	-2.68102	131770	-1.48007	131770

Reaction moments Sleeve

Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N-m	0	0	0	0

Reaction forces Piston rod

Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N	-0.0417544	-131791	0.99162	131791

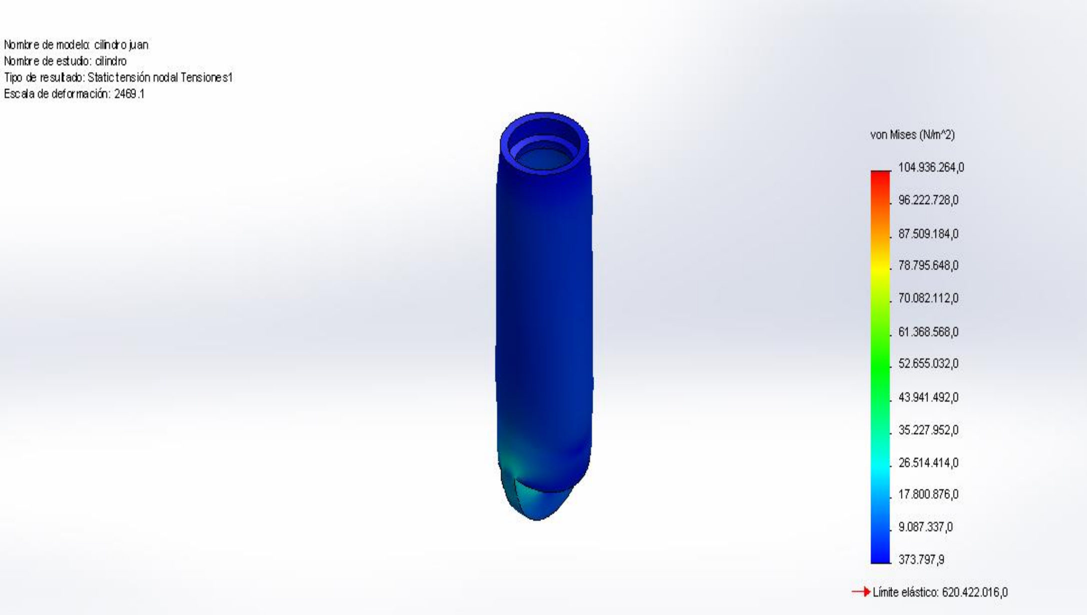
Reaction moments Piston rod

Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N-m	0	0	0	0

Study results

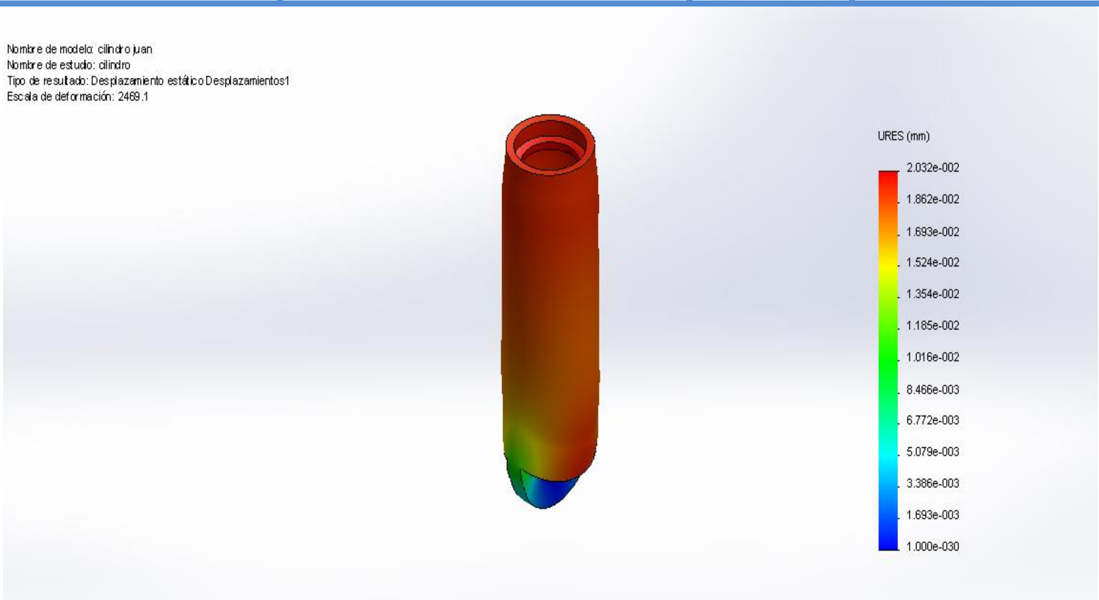
<u>Sleeve</u>

Name	Type	Min.	Max.
Stress1	VON: Von Mises stress	373798 N/m^2 Node: 70375	1.04936e+008 N/m^2 Node: 89918



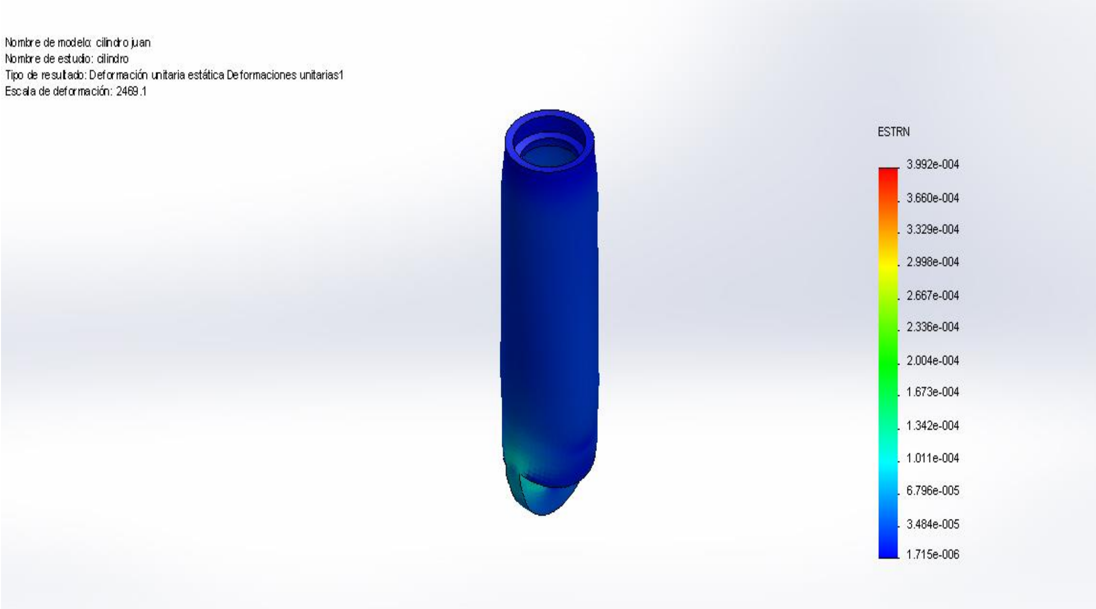
Sleeve – Stress 1

Name	Type	Min.	Max.
Displacement 1	URES: Resulting displacement	0 mm Node: 1	0.0203175 mm Node: 69478



Sleeve – Displacement 1

Name	Type	Min.	Max.
Strain	ESTRN: Equivalent strain	1.71463e-006 Element: 31701	0.000399165 Element: 20031

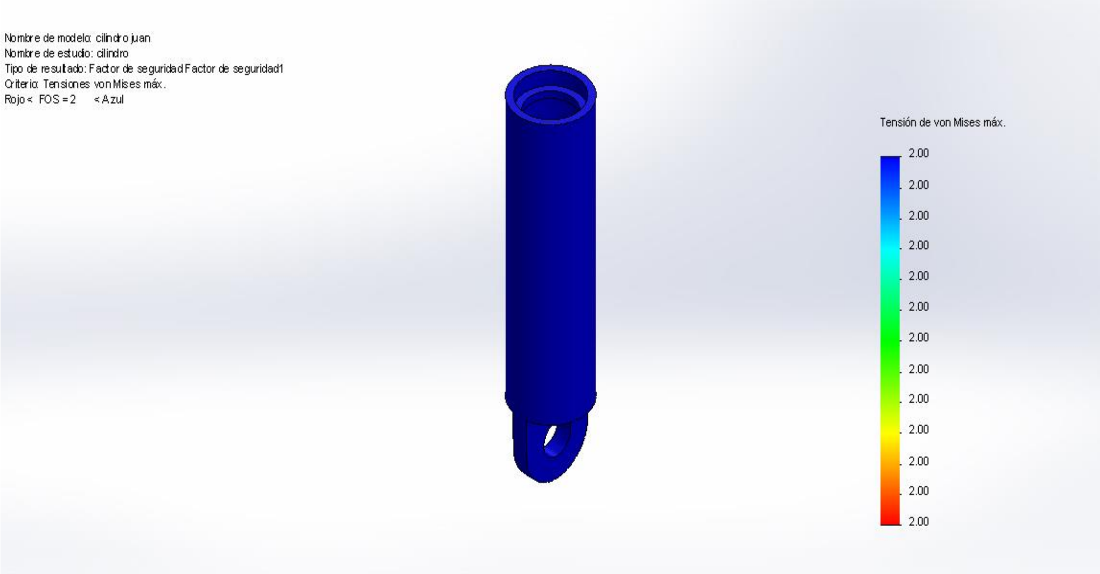


Sleeve – Strain 1

Name	Type
Displacement 1	Deformed shape

Sleeve – Displacement 1

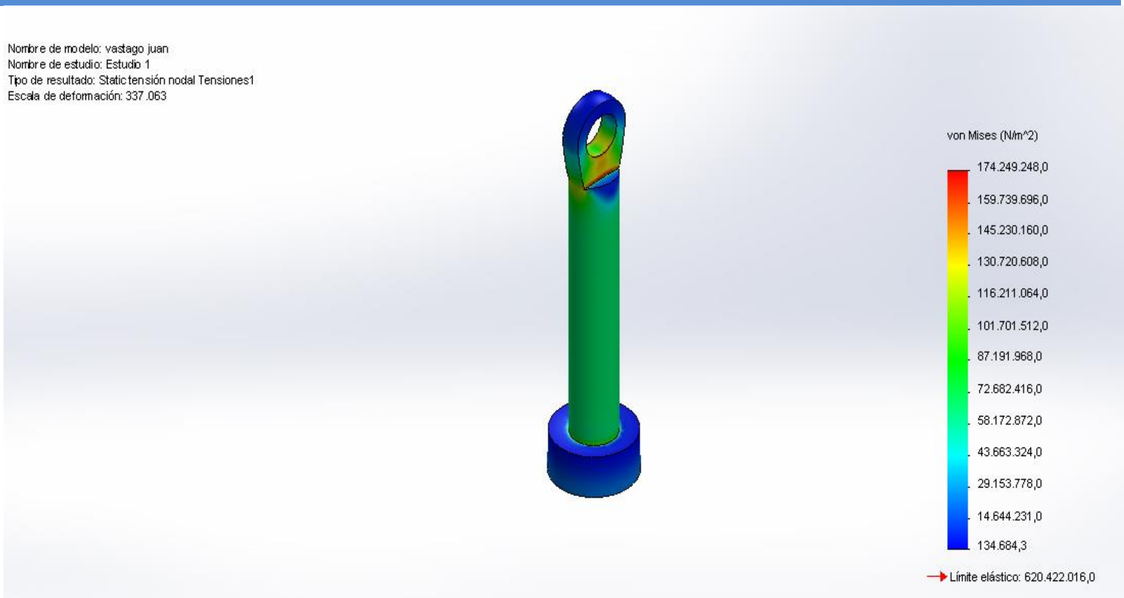
Name	Type	Min.	Max.
Safety factor 1	Max. Von Mises stress	5.91237 Node: 89918	1659.78 Node: 70375



Sleeve – Safety factor 1

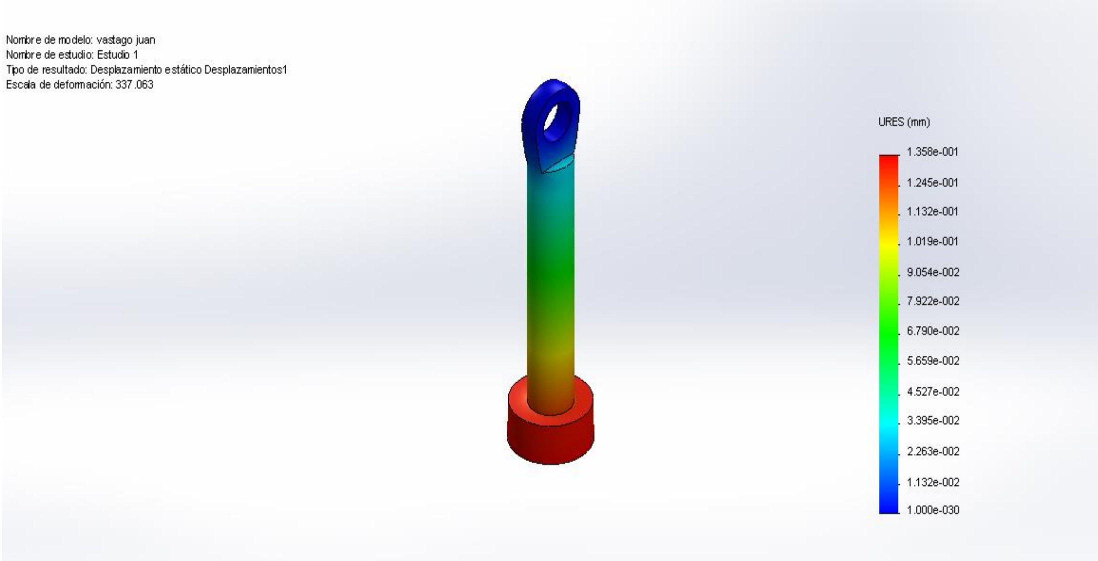
Piston rod

Name	Type	Min.	Max.
Stress1	VON: Von Mises stress	134684 N/m^2 Node: 69430	1.74249e+008 N/m^2 Node: 47454



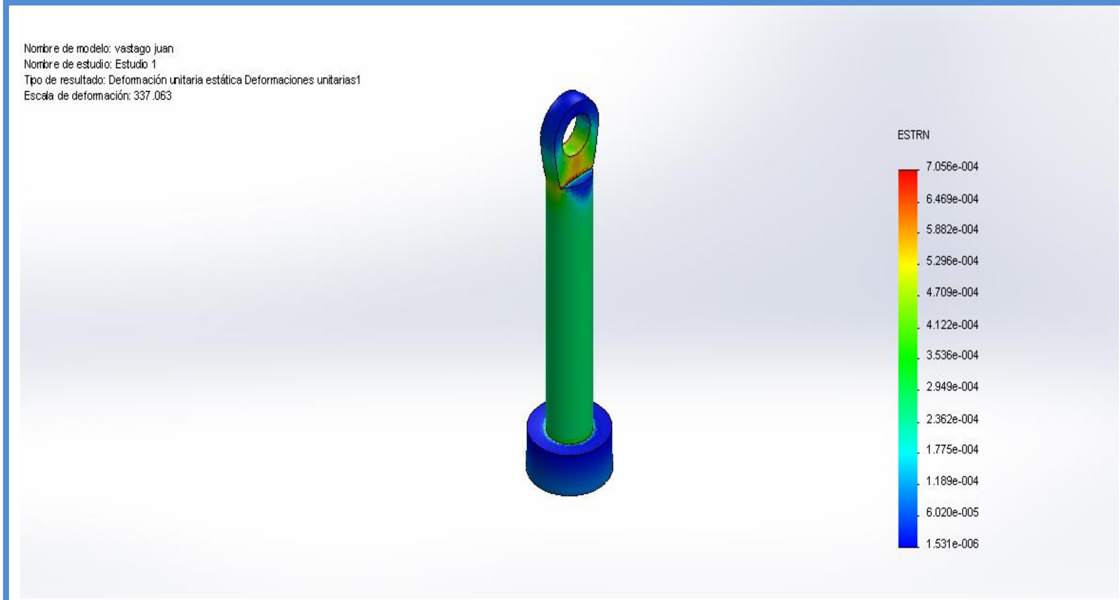
Piston rod – Stress 1

Name	Type	Min.	Max.
Displacement 1	URES: Resulting displacement	0 mm Node: 1	0.135806 mm Node: 2038



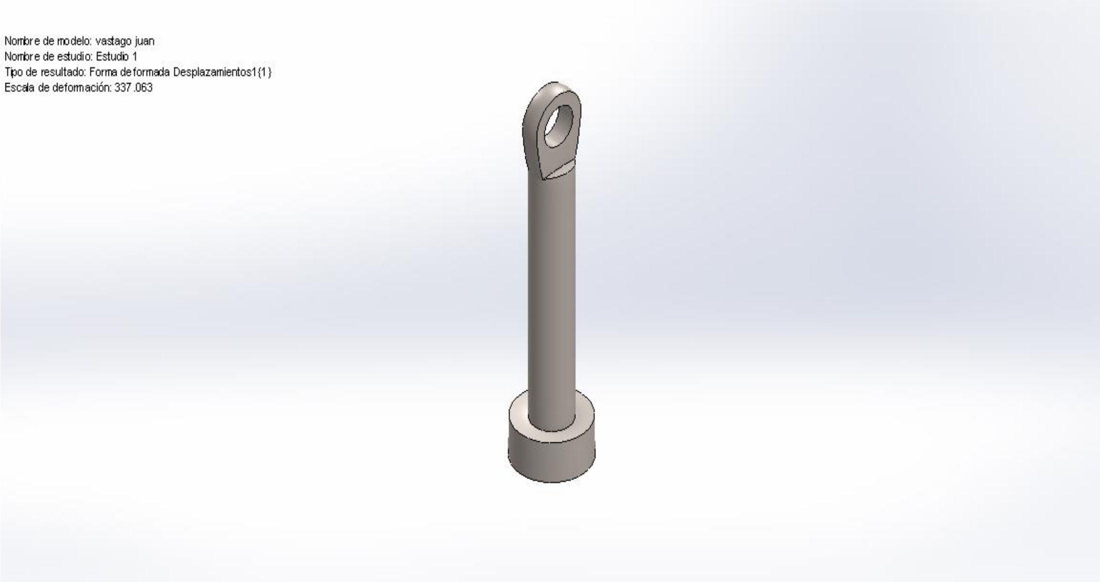
Piston rod – Displacement 1

Name	Type	Min.	Max.
Strain	ESTRN: Equivalent strain	1.53149e-006 Element: 13838	0.000705569 Element: 9802



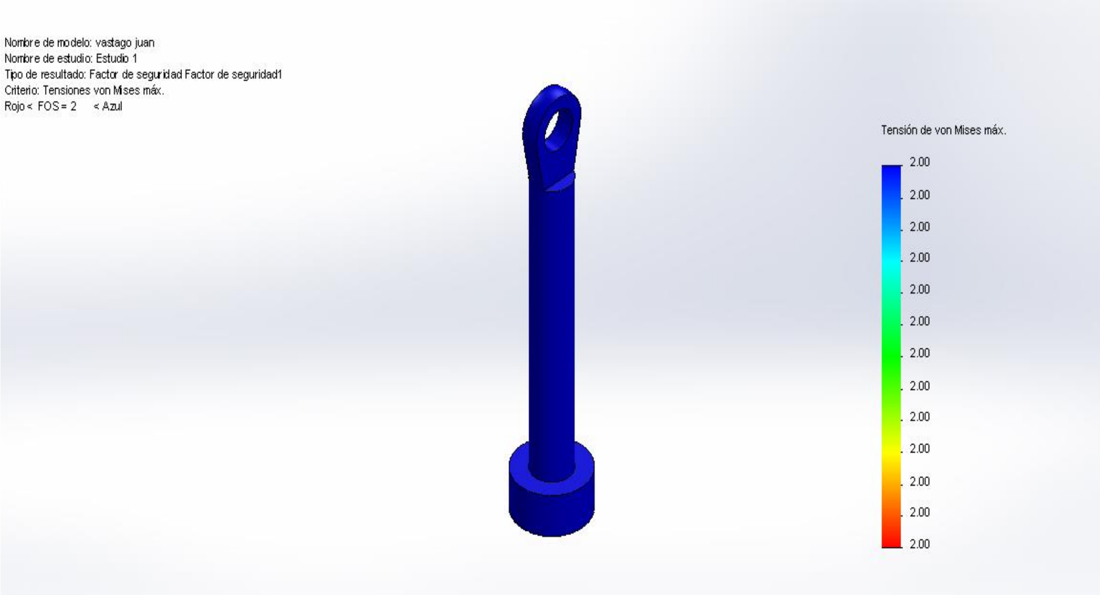
Piston rod – Strain 1

Name	Type
Displacement 1	Deformed shape



Piston rod – Displacement 1

Name	Type	Min.	Max.
Safety factor 1	Max. Von Mises stress	3.56054 Node: 47454	4606.49 Node: 69430



Piston rod – Safety factor 1

6.3.3 ANALYSIS OF THE MAIN BODY

The fixed part has been established on the upper part of the main body, just where a pin would be placed to sustain the model.

We have set the reaction forces (both horizontal and vertical) on the eight places: four above (VE and HE) and four below (VA and HA).

We have applied also the component of the gravity.

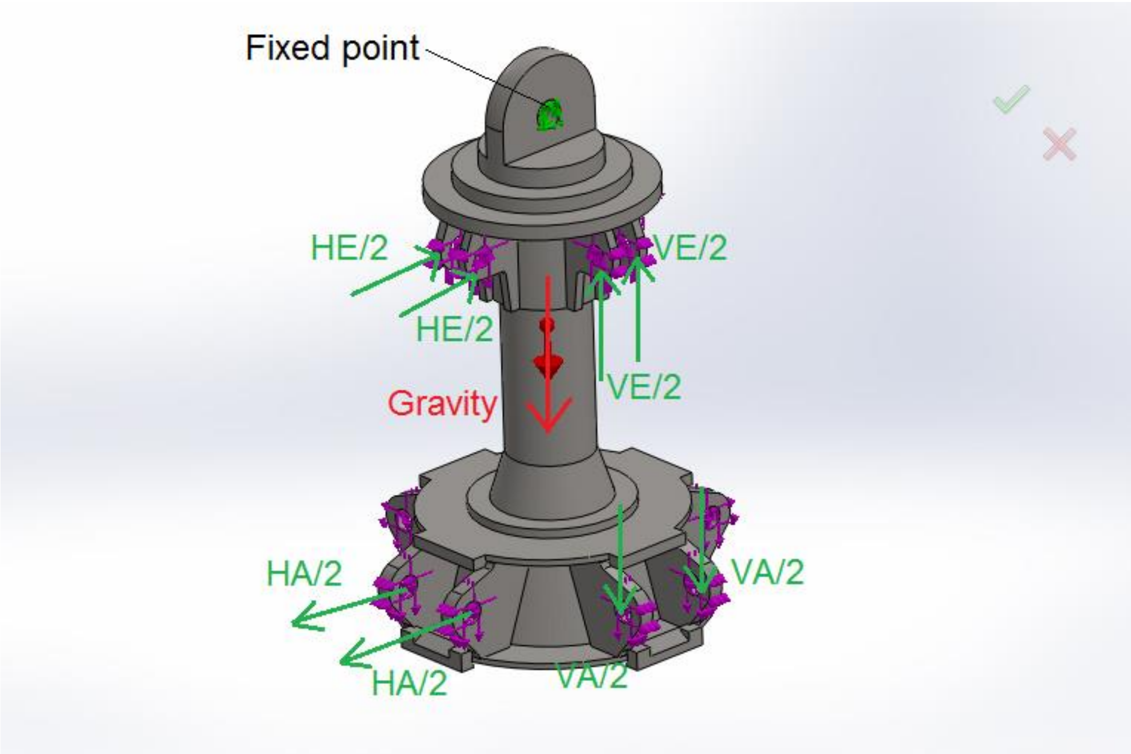
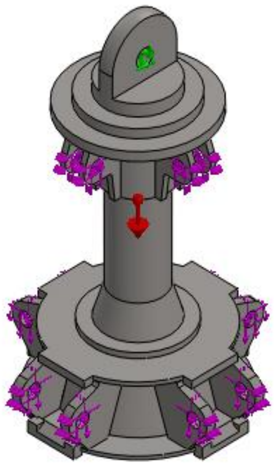


Figure 38: Main body simulation

Model information



Name of the model: Main body

Solid			
Name and reference document	**Treaty as**	**Volumetric properties**	**Path to document / Date modified**
Cortar-Extruir5 	Solid	**Mass:363.008 kg** **Volume:0.047144 m^3** **Density:7700 kg/m^3** **Weight: 3557.48 N**	**C:\Users\Juan\Desktop\PROYECTO\Carcasa principal.SLDPRT** Jun 17 00:10:53 2013

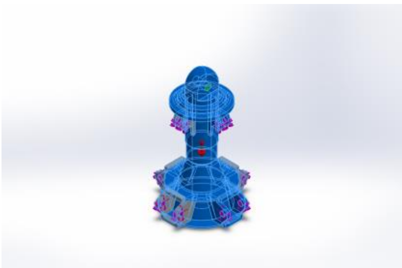
Study properties

Name of the study	Main body
Analysis type	Static
Mesh type	Solid mesh
Calculate free body forces	Activate
Results folder	Documento de SolidWorks (C:\Users\Juan\Desktop\PROYECTO)

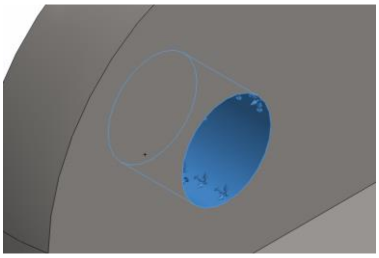
Units

Units system	Metric
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

Material properties

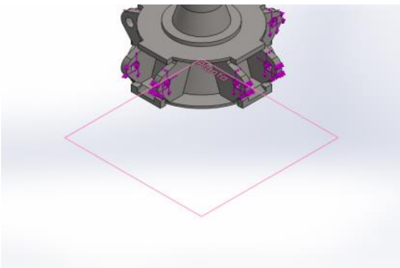
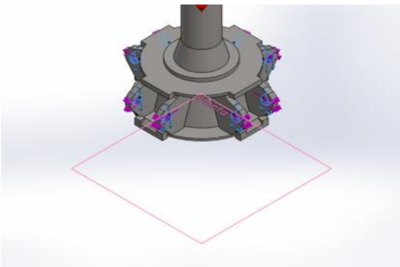
Model reference	Properties
	**Name:** Alloy Steel **Model type:** Isotropic elastic lineal **Yield limit:** 6.20422e+008 N/m^2 **Tensile strength:** 7.23826e+008 N/m^2 **Modulus of elasticity:** 2.1e+011 N/m^2 **Poisson coefficient:** 0.28 **Density:** 7700 kg/m^3

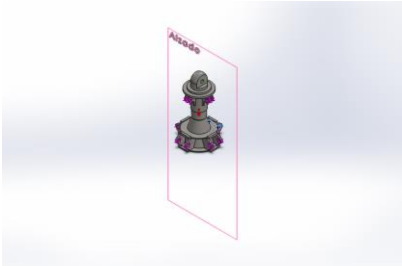
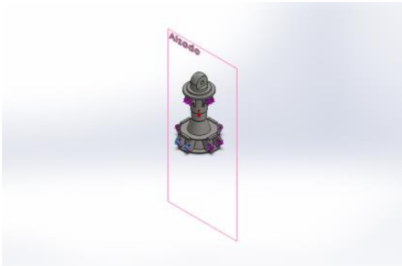
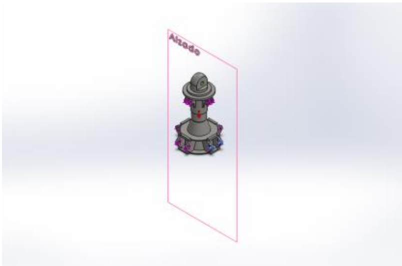
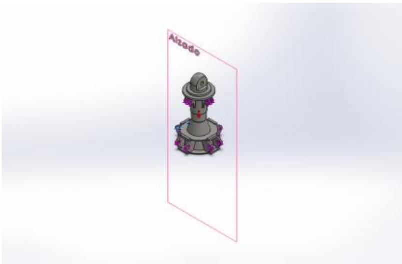
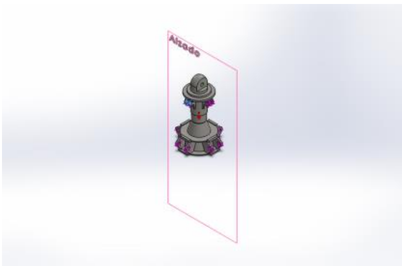
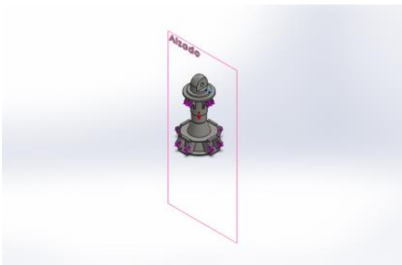
Loads and Restrains

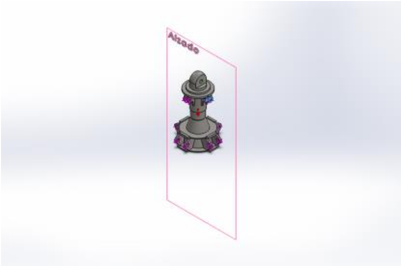
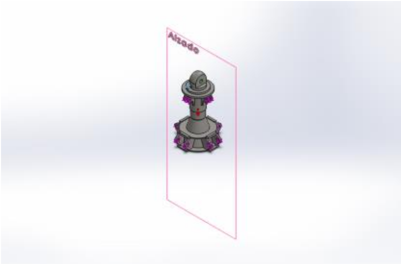
Clamping name	Clamping picture	Clamping details
Fixed-1		**Entities:** 1 face(s) **Type:** Fixed geometry

Resulting forces

Components	X	Y	Z	Resulting
Reaction force(N)	0.153134	17041.2	-0.0184708	17041.2
Reaction moment(N-m)	0	0	0	0

Load name	Load picture	Load details
Gravity-1		**Reference:** Top view **Values:** 0 0 -9.81 **Units:** SI
Force -1		**Entities:** 8 face(s), 1 plan(s) **Reference:** Top view **Type:** Apply force **Values:** ---, ---, -63995 N
Force -2		**Entities:** 8 face(s), 1 plan(s) **Reference:** Top view **Type:** Apply force **Values:** ---, ---, 62310 N

Force -3		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** ---, ---, -34763.5 N
Force -4		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** ---, ---, 34763.5 N
Force -5		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** 34763.5, ---, --- N
Force -6		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** -34763.5, ---, --- N
Force -7		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** ---, ---, 21401 N
Force -8		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** ---, ---, -21401 N

Force -9		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** 21401, ---, --- N
Force -10		**Entities:** 2 face(s), 1 plan(s) **Reference:** Front view **Type:** Apply force **Values:** -21401, ---, --- N

Mesh information

Mesh type	Solid mesh
Mesher used	Standar mesh
Automatic transition	Desactivate
Include automatic mesh loops	Desactivate
Jacobeans points	4 points
Size of elements	19.2169 mm
Tolerance	0.960845 mm
Mesh quality	Higher order quadratic elements

Mesh information - Details

Total number of nodes	90337
Total number of elements	53026
Maximum aspect ratio	33.485
% of elements with aspect ratio < 3	97.6
% of elementes with aspect ratio > 10	0.173
% of distorted elements	0
Time to complete de mesh (hh;mm;ss)	00:00:13
Computer name	JUAN-PC

Resulting forces

Reaction forces

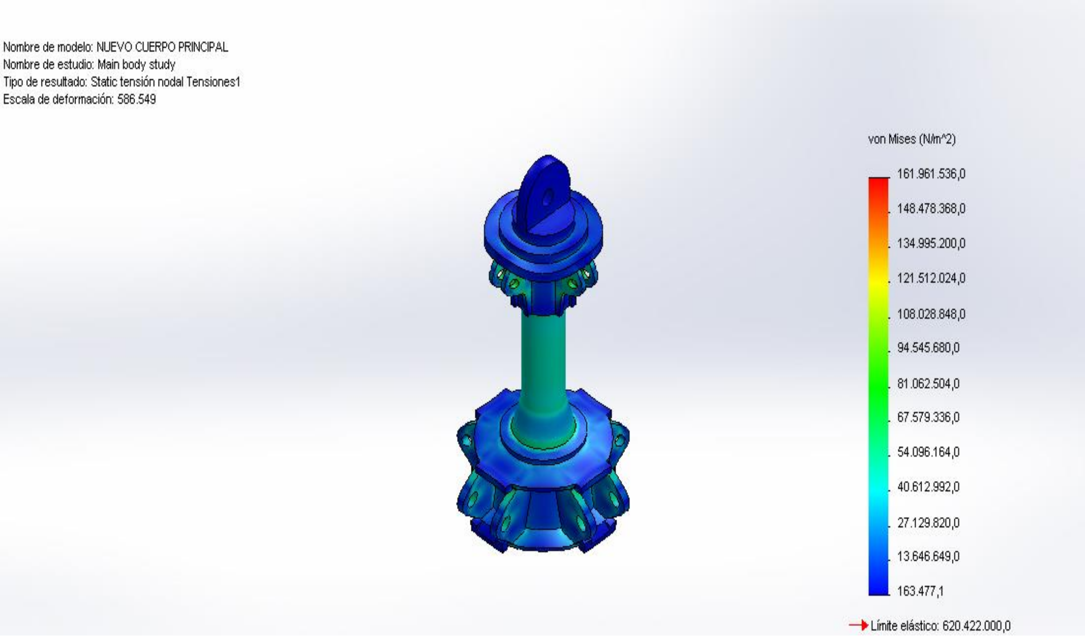
Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N	0.153134	17041.2	-0.0184708	17041.2

Reaction moments

Selection set	Units	Sum X	Sum Y	Sum Z	Resulting
Entire model	N-m	0	0	0	0

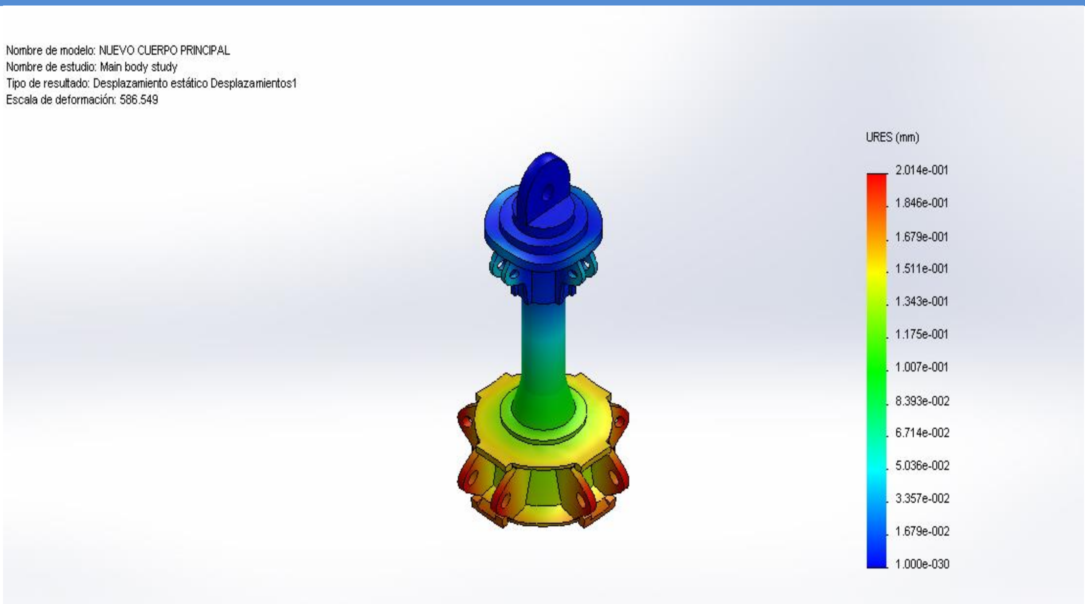
Study results

Name	Type	Min.	Max.
Stress 1	VON: Von Mises stress	163477 N/m^2 Node: 3778	1.61962e+008 N/m^2 Node: 37165



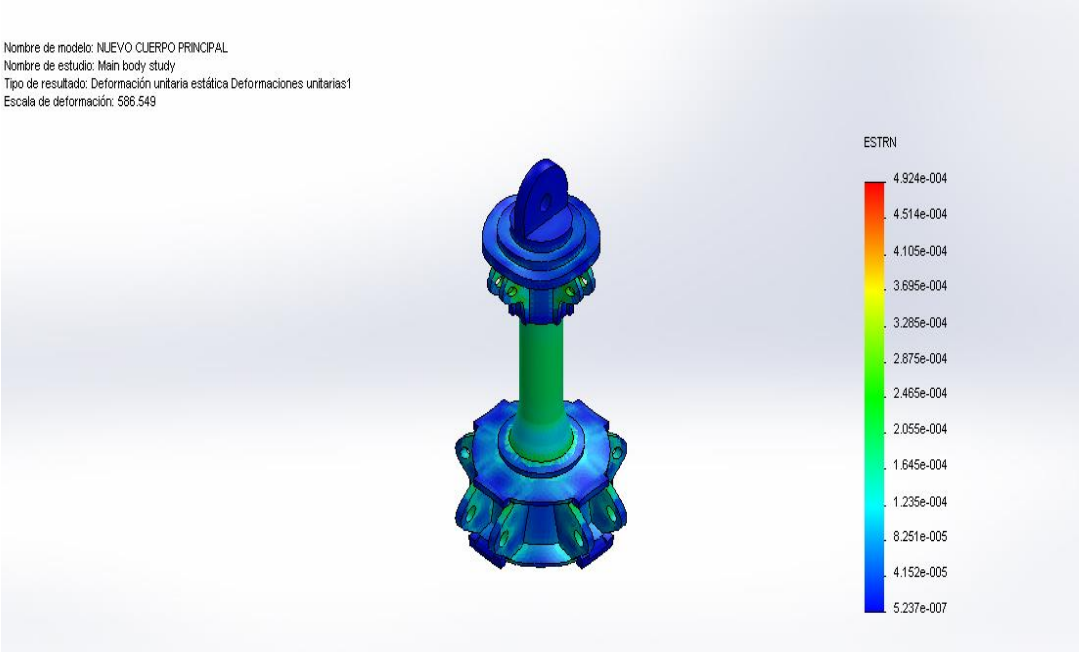
Main body – Stress 1

Name	Type	Min.	Max.
Displacement 1	URES: Resulting displacement	0 mm Node: 1033	0.20142 mm Node: 48682



Main body – Displacement 1

Name	Type	Min.	Max
Strain 1	ESTRN: Equivalent strain	5.23678e-007 Element: 50398	0.00049244 Element: 16073

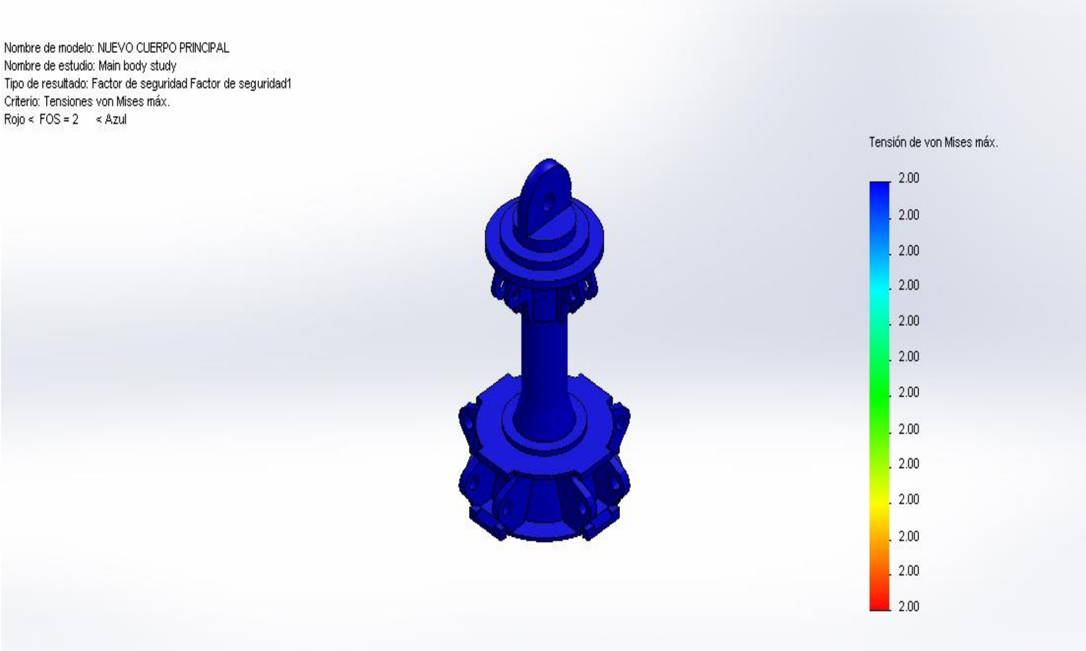


Main body – Strain 1

Name	Type
Displacement 1	Deformed shape

Main body – Displacement 1

Name	Type	Min.	Max.
Safety factor 1	Max. Von Mises stress	3.83067 Node: 37165	3795.16 Node: 3778



Main body – Safety factor 1

7. OPTIMIZATION

7.1 MASS REDUCTION

For mass reduction, we will remove some material from the main model in order to reduce weight.

A reduction of mass involves a reduction in the cost of the material and, consequently, a reduction in the cost of the model.

The element we have chosen to lighten is the tong, for the following reasons:

- It is not easy to reduce the cylinder weight, because its length can't be changed (we need the same length to move our orange peel grapple).

- The main body is difficult to lighten as well for a similar reason. The height and diameters can't be changed, because the rest of the elements have to be positioned with those sizes.

In this way, we have removed some material and the tong looks like:

Figure 39: Mass reduced tong (Section view)

Before the material removal, it had the following shape:

Figure 40: Original tong (Section view)

Remembering the previous weight:

$$Wt = 126.27767\ kg * 9.8 \frac{m}{s^2} = 1237.5\ N$$

And the new weight of the tong is:

$$Wt' = 99.63934\ kg * 9.8 \frac{m}{s^2} = 976.5\ N$$

So we have reduced 21% of the mass. The impacts of this mass reduction are:

- Reduction of the price because of the reduction of material
- The cylinder would have to make a slightly higher force:

$$Scyl = 132720\ N$$

This value is very similar to the previous one.

We can use this reduction to lift a heavier load. If the total reduction of weight has been:

$$(126.27767\ kg - 99.63934\ kg) * 4\ peels = 106\ kg$$

We could raise a load of:

$$780\ kg + 106\ kg = 886\ kg$$

But this will have some repercussions on the force of the cylinder:

$$S' = 30435\ N\ (new\ weight\ of\ the\ load\ per\ peel)$$

$$Scyl = \frac{S' * dAS - Wt' * dAWt}{dAScyl}$$

This Scyl will be increased because of the effect of bigger load but will be reduced because of the effect of a lower weight. Introducing the new data in the equations:

$$Scyl = 151140\ N$$

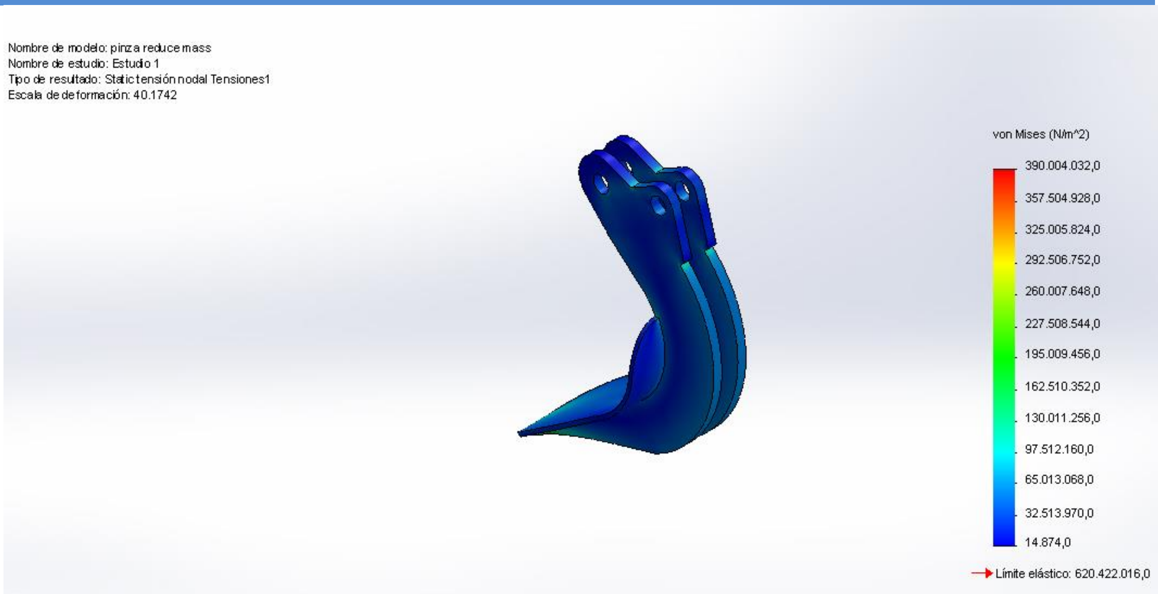
So the force that the cylinder has to apply is bigger.

And now we will execute the simulation of stress on the tong with the new cylinder force:

$$VB = 142970\ N$$

$$HB = 49010\ N$$

Name	Type	Min.	Max.
Stress 1	VON: Von Mises stress	14874 N/m^2 Node: 3773	3.90004e+008 N/m^2 Node: 2107



Tong Mass Reduction – Stress 1

In the tong without the mass reduction, the maximum stress was 3.16e+008 $\mathrm{N/m^2}$and with the mass reduction, the maximum stress is 3.9e+008 $\mathrm{N/m^2}$. So we are still well below the yield limit.

7.2 EXTRA TONG

In this section, we will study the addition of a new tong to the model (5 tongs).

Although it is not exactly an optimization of the main model, it will be useful if we want to lift more weight with the same model but with one more tong. In this way, it will not be necessary to perform a completely new design.

We are going to do two types of analysis:

1.- Checking the new force that the cylinder has to make. This is a very easy analysis because the only thing we have to change, is the force of the load per peel. Instead of dividing this load by 4, we have to divide it by 5. In this way, the new cylinder's force is:

$$Scyl = 104870\ N$$

2.- We start from the weight value that we know the tong can resist (calculated in previous points) and later we will do the same calculation until we know what could be the weight we can lift with five peels.

$$Scyl = 131821.845\ N$$

$$S = \frac{Scyl * dAScyl + Wt * dAWt}{dAS}$$

$$S = 26763\ N$$

$$M = \frac{5 * S * \cos(\omega)\ N}{9.8\ m/s^2}$$

$$M = 974\ kg$$

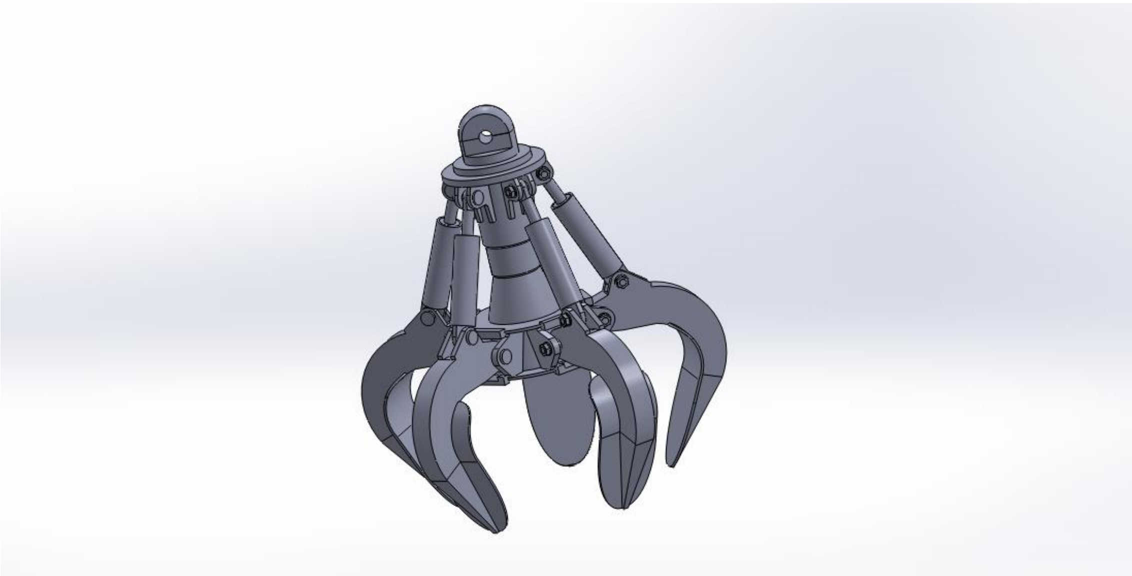


Figure 41: 5 peel grapple design

An experiment with six tongs or more is not possible because of problems with the space in the main body of the orange peel grapple.

8. CONCLUSIONS

We have managed to achieve all the goals that were proposed in this project.

The threads in the pins haven't been designed because in the analysis we have done there aren't forces in their longitudinal way.

The maximum levels of stress (shown in the point 6) of the initial design are under the yield limit of the material accomplishing with the safety factors.

We can see the safety factor of each important element in the point 6 too. It is calculated as yield limit divided by the maximum stress that an element can withstand.

Element	Minimum safety factor
Peel	1.9636
Sleeve cylinder	5.91237
Piston rod cylinder	3.56054
Main body	3.83067
Peel (optimization)	1.5897

The safety factor of the peel is almost 2. Excluding the optimization of the peel, the rest of the components have a good safety factor. The optimized peel has a safety factor of almost 1.6, which is not a very good factor, but we still are on the side of safety.

We have to check if the cylinders will exceed their pressure due to the force they have to perform. We will take the force of Scyl and we will divide it by the area on which this force is applied (the area is the lower part of the piston rod)

$$P = \frac{Scyl}{Area} = \frac{131821.845\ N}{0.006647\ m^2}$$

$$P = 19831780.5\ Pa = 195.72\ bar$$

The operation pressure of the cylinder is 400 bar. Since 195.72 < 400 bar, our cylinder will perfectly withstand this maximum force.

Sometimes, the program SolidWorks gives us some reactions along the “z” axis, but this is due to small variations by the mesh when the simulation has been run.

As it is possible to see, these reactions on the “z” axis are really small and can be easily neglected in relation to rest of reactions or forces.

We are going to check that the pins don’t fail because of cut:

The limit cut stress is:

$$\tau_{lim} = 0.5 * \sigma_{lim} = 0.5 * 620 \cdot 10^6 \frac{N}{m^2} = 310 \cdot 10^6 \frac{N}{m^2}$$

$$\tau = \frac{Strength}{Area * 2\ cutting\ area}$$

$$Area = \pi * R^2$$

$$Safety\ factor = \frac{\tau_{lim}}{\tau}$$

We have 3 different pins, one in the point A, other in B and the last one in E.

Pin	**Radius (m)**	**Area ($\mathbf{m^2}$)**	**Force (N)**	**τ (N/$\mathbf{m^2}$)**	**Safety factor**
Point A	0.0235	1.735e-3	145655	41.9e+6	7.39
Point B	0.0235	1.735e-3	131821	37.9e+6	8.18
Point E	0.0215	1.452e-3	131760	45.3e+6	6.84

Pins can fail by crushing also:

$$\sigma_{lim} = 620 \cdot 10^6 \frac{N}{m^2}$$

$$\sigma = \frac{Strength}{Area}$$

$$Area = 2 * R * e$$

$$e = \sum Lengths$$

$$Safety\ factor = \frac{\sigma_{lim}}{\sigma}$$

Pin	Radius (m)	e (m)	Area (m^2)	Force (N)	σ (N/m^2)	Safety factor
Point A	0.0235	0.164	0.0077	145655	18.92e+6	32.77
Point B	0.0235	0.073	0.0034	131821	38.77e+6	15.99
Point E	0.0215	0.061	0.0026	131760	50.68e+6	12.23

Since we have not considered longitudinal force in our model, we do not calculate the traction forces.

We can see that all the pins have a high safety factor, so they can be used for our model.

Talking about the optimization:

The optimizations proposed are viable, although the safety factor of the mass reduction is a little bit low, but is still over 1.

The mass reduction optimization allows a decrease in the price of the material, but it would be necessary to check if the manufacturing cost would increase more than this decrease in price. The pressure in the cylinder with this new force also is below the operation pressure of the cylinder:

$$P = \frac{151140\ N}{0.006647\ m^2} = 224.4\ bar$$

With the extra tong optimization, we could raise 194 kg more in our model. But this increase in the capacity of lift carries an increase in the price because we have to use more material for the extra tong.

The calculation of the theoretical analysis has been done helped by the program Matlab. This has been a good idea since it has allowed us to easily and quickly change some equations or data and obtain all the information we have needed.

The Matlab equations are shown in the annex in point 10.2.

9. LITERATURE

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[4] www.fernie.es/

[5] www.genscoequip.com

[6] www.google.com

[7] www.hidroelevadoresherrero.com/

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[11] www.rotobec.com

[12] www.solidworks.com

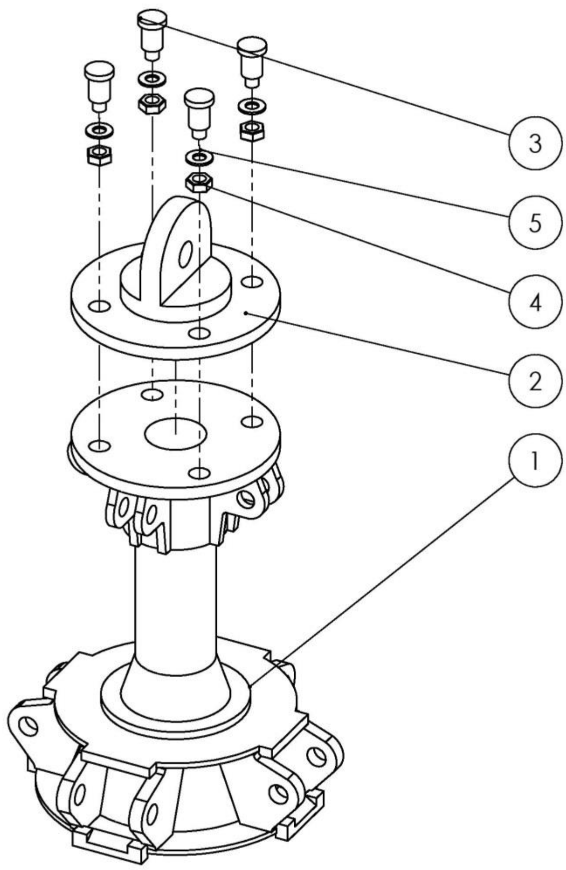
[13] www.verachtert.dk/

10. ANNEX

10.1 PLANS OF THE MODEL

We are going to show first the plans of the assembly of the elements and the way that they have been connected.

The main body has been analyzed during this project as one unique solid element, but it would have to be assembly by two parts: the main body and an element on the top that can rotate or not. In the following plans, we will show the main body as two elements.



ITEM NO.	PART NUMBER	manual explode/QTY.
1	Main body (bottom)	1
2	Main body (top)	1
3	Pin	4
4	Nut	4
5	Washer	4

SI NO SE INDICA LO CONTRARIO:
LAS COTAS SE EXPRESAN EN MM
ACABADO SUPERFICIAL:
TOLERANCIAS:
LINEAL:
ANGULAR:

ACABADO:

REBARBAR Y ROMPER ARISTAS VIVAS

NO CAMBIE LA ESCALA

REVISIÓN

	NOMBRE	FIRMA	FECHA			
DIBUJ.						
VERIF.						
APROB.						
FABR.						
CALID.				MATERIAL:		

TÍTULO:

N.º DE DIBUJO

Main body

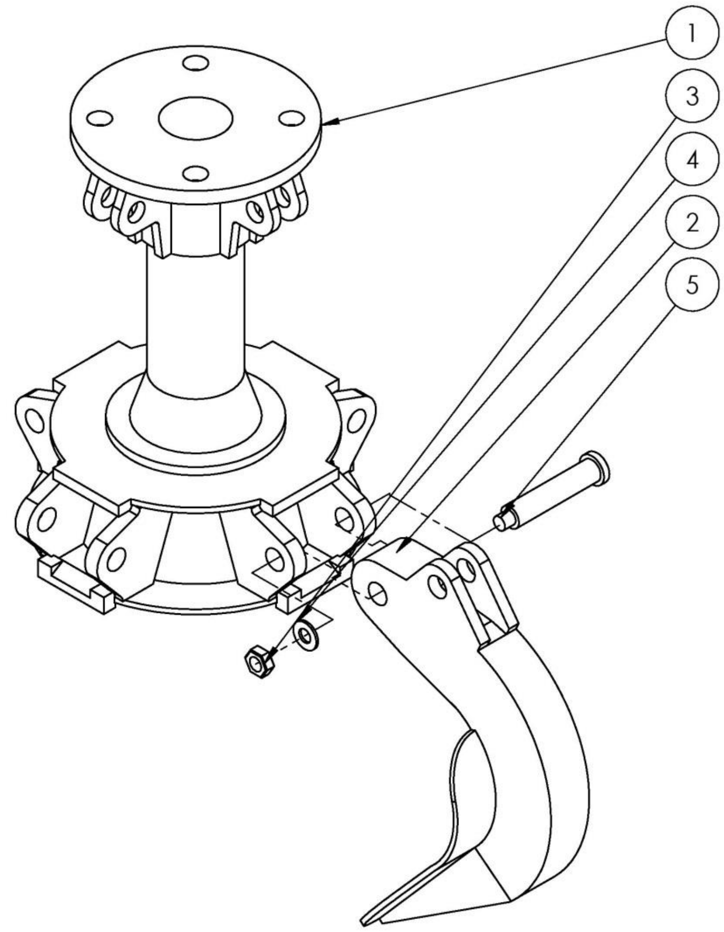
A4

PESO:

ESCALA:1:20

HOJA 1 DE 1

Figure 42: Main body assembly



ITEM NO.	PART NUMBER	manual explode/QTY.
1	Main body (bottom)	1
2	Peel	1
3	Nut	1
4	Washer	1
5	Pin Main body - Peel	1

SI NO SE INDICA LO CONTRARIO:
LAS COTAS SE EXPRESAN EN MM
ACABADO SUPERFICIAL:
TOLERANCIAS:
LINEAL:
ANGULAR:

ACABADO:

REBARBAR Y ROMPER ARISTAS VIVAS

NO CAMBIE LA ESCALA

REVISIÓN

	NOMBRE	FIRMA	FECHA		
DIBUJ.					
VERIF.					
APROB.					
FABR.					
CALID.					

TÍTULO:

MATERIAL:

N.º DE DIBUJO **Main body - Peel**

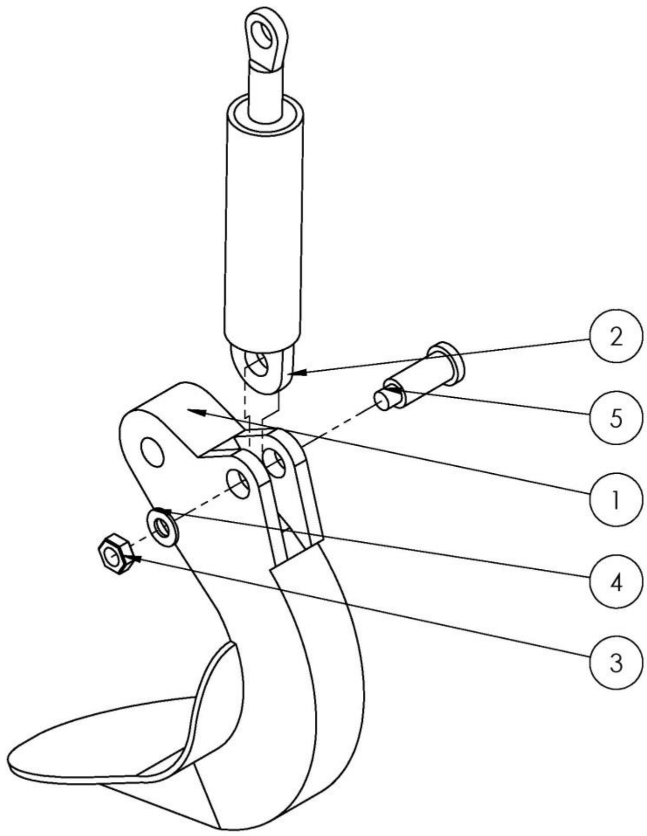
A4

PESO:

ESCALA:1:50

HOJA 1 DE 1

Figure 43: Main body – Peel assembly



ITEM NO.	PART NUMBER	manual explode/QTY.
1	Peel	1
2	cylinder	1
3	Nut	1
4	Washer	1
5	Pin Peel - Cylinder	1

SI NO SE INDICA LO CONTRARIO:
LAS COTAS SE EXPRESAN EN MM
ACABADO SUPERFICIAL:
TOLERANCIAS:
LINEAL:
ANGULAR:

ACABADO:

REBARBAR Y ROMPER ARISTAS VIVAS

NO CAMBIE LA ESCALA

REVISIÓN

	NOMBRE	FIRMA	FECHA
DIBUJ.			
VERIF.			
APROB.			
FABR.			
CALID.			

TÍTULO:

MATERIAL:

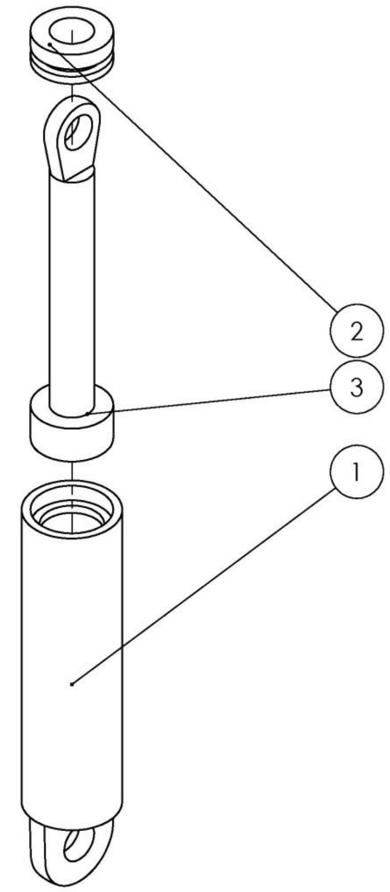
N.º DE DIBUJO **Peel - Cylinder** A4

PESO:

ESCALA:1:20

HOJA 1 DE 1

Figure 44: Peel – Cylinder assembly



ITEM NO.	PART NUMBER	manual explode/QTY.
1	Sleeve	1
2	Cylinder top	1
3	Piston rod	1

SI NO SE INDICA LO CONTRARIO:
LAS COTAS SE EXPRESAN EN MM
ACABADO SUPERFICIAL:
TOLERANCIAS:
LINEAL:
ANGULAR:

ACABADO:

REBARBAR Y ROMPER ARISTAS VIVAS

NO CAMBIE LA ESCALA

REVISIÓN

	NOMBRE	FIRMA	FECHA
DIBUJ.			
VERIF.			
APROB.			
FABR.			
CALID.			

TÍTULO:

MATERIAL:

N.º DE DIBUJO Cylinder

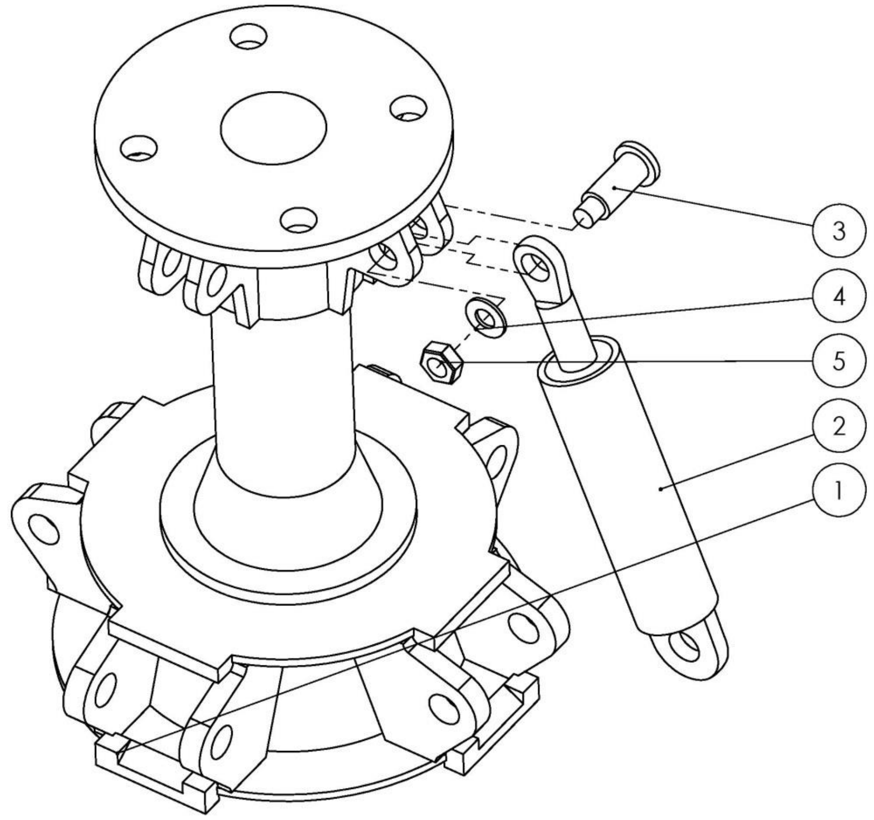
A4

PESO:

ESCALA:1:10

HOJA 1 DE 1

Figure 45: Cylinder assembly



ITEM NO.	PART NUMBER	manual explode/QTY.
1	Main body	1
2	Cylinder	1
3	Pin Cylinder - Main body	1
4	Washer	1
5	Nut	1

SI NO SE INDICA LO CONTRARIO:
LAS COTAS SE EXPRESAN EN MM
ACABADO SUPERFICIAL:
TOLERANCIAS:
LINEAL:
ANGULAR:

ACABADO:

REBARBAR Y ROMPER ARISTAS VIVAS

NO CAMBIE LA ESCALA

REVISIÓN

	NOMBRE	FIRMA	FECHA
DIBUJ.			
VERIF.			
APROB.			
FABR.			
CALID.			

MATERIAL:

TÍTULO:

N.º DE DIBUJO

Cylinder - Main body

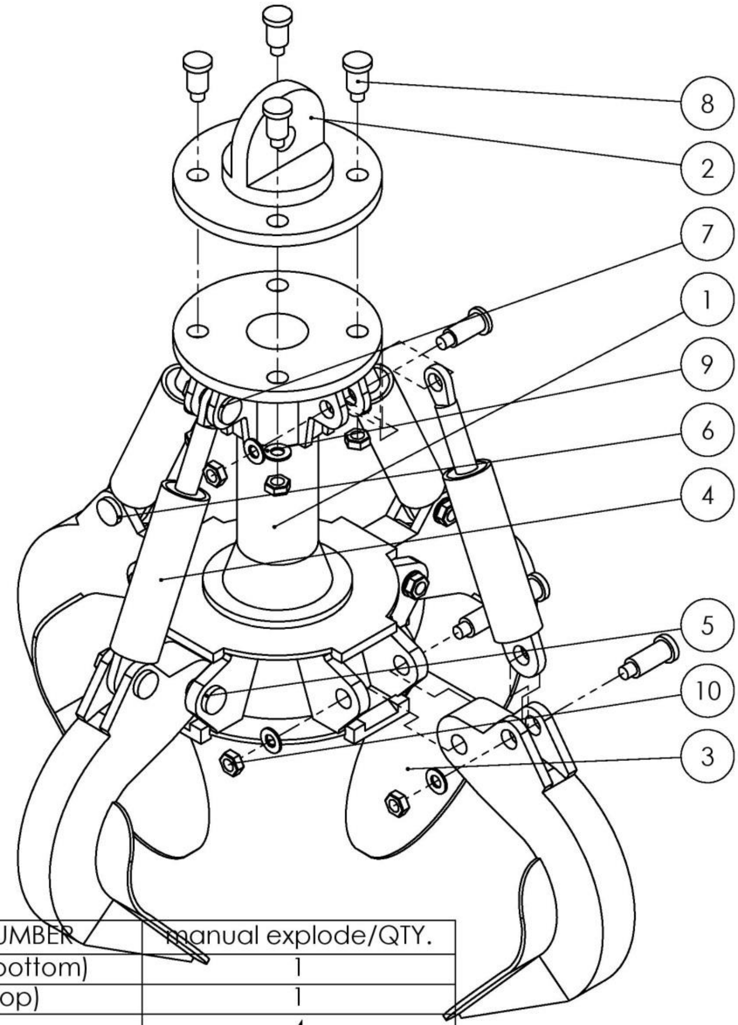
A4

PESO:

ESCALA:1:20

HOJA 1 DE 1

Figure 46: Cylinder – Main body assembly



ITEM NO.	PART NUMBER	manual explode/QTY.
1	Main body (bottom)	1
2	Main body (top)	1
3	Peel	4
4	Cylinder	4
5	Pin Main body - Peel	4
6	Pin Peel - Cylinder	4
7	Pin Cylinder - Main body	4
8	Pin	4
9	Washer	16
10	Nut	16

SI NO SE INDICA LO CONTRARIO: LAS COTAS SE EXPRESAN EN MM ACABADO SUPERFICIAL: TOLERANCIAS: LINEAL: ANGULAR:
ACABADO:
REBARBAR Y ROMPER ARISTAS VIVAS
NO CAMBIE LA ESCALA
REVISIÓN

	NOMBRE	FIRMA	FECHA
DIBUJ.			
VERIF.			
APROB.			
FABR.			
CALID.			

TÍTULO:
MATERIAL:
N.º DE DIBUJO
Orange Peel Grapple
A4
PESO:
ESCALA:1:50
HOJA 1 DE 1

Figure 47: Orange Peel Grapple assembly

10.2 CALCULATION WITH PROGRAMMING SOFTWARE

In order to make the calculations easier, we have designed the necessary equations that we need for this project.

Introducing the input data, this code will give us all the data we want.

And doing little changes, we can obtain other information, like the performed optimization in the point 7.

This is the Matlab code:

```
function project

    %Load mass

        M=

    %number of peels

        n=

    %Position (angle alfa)

        alfa=

    %Fixed angles

        alfazero=11.10*2*pi/360;
        omegazero=28.61*2*pi/360;
        beta=46.16*2*pi/360;
        gamma=25.69*2*pi/360;

    %Fixed distances

        dAB=0.18195;
        dAE=0.7081;
        dAG=0.34222;
        dAH=0.76441;
        dBG=0.35201;
        dBH=0.87908;
        dGH=0.58222;
        XAE=0.11459;
        YAE=0.69877;
        dBF=dBH*cos(alfazero+beta-omegazero);

    %Calculation omega

        omega=alfa+beta-acos(dBF/dBH);
```

```
%Load weight

    Wl=M*9.8;

%Load weight per peel

    wl=Wl/n;

%Force in the peel

    S=wl/cos(omega);

%Tong mass

    m=126.27767;

%Tong weight

    Wt=m*9.8;

%Cylinder mass

    mc=22.78713;

%Cylinder weight

    Wcyl=mc*9.8;

%Main body mass

    mmb=556.33134;

%Main body weight

    Wmb=mmb*9.8;

%Calculating theta

    XAB=dAB*cos(alfa);
    YAB=dAB*sin(alfa);
    epsilon=atan((XAB+XAE)/(YAE-YAB));
    theta=(pi/2)-epsilon;

%Equations

    dAWt=dAB*cos(alfa)-dBG*cos(alfa+beta+gamma);
    dAS=dBH*cos(alfa+beta-omega)-dAB*cos(omega-alfa);
    dAScyl=dAB*sin(alfa+theta);

    Scyl=(S*dAS-Wt*dAWt)/dAScyl

%Reactions A

    VA=wl+Wt+Scyl*sin(theta)
    HA=Scyl*cos(theta)+S*sin(omega)
```

```
        RA=(VA^2+HA^2)^0.5

    %Reactions B

        VB=Scyl*sin(theta)
        HB=Scyl*cos(theta)
        RB=(VB^2+HB^2)^0.5

    %Reactions E

        VE=VB-Wcyl
        HE=HB
        RE=(VE^2+HE^2)^0.5

    %Reactions I

        VI=Wmb+n*VA-n*VE
        HI=0
        RI=(VI^2+HI^2)^0.5

end
```